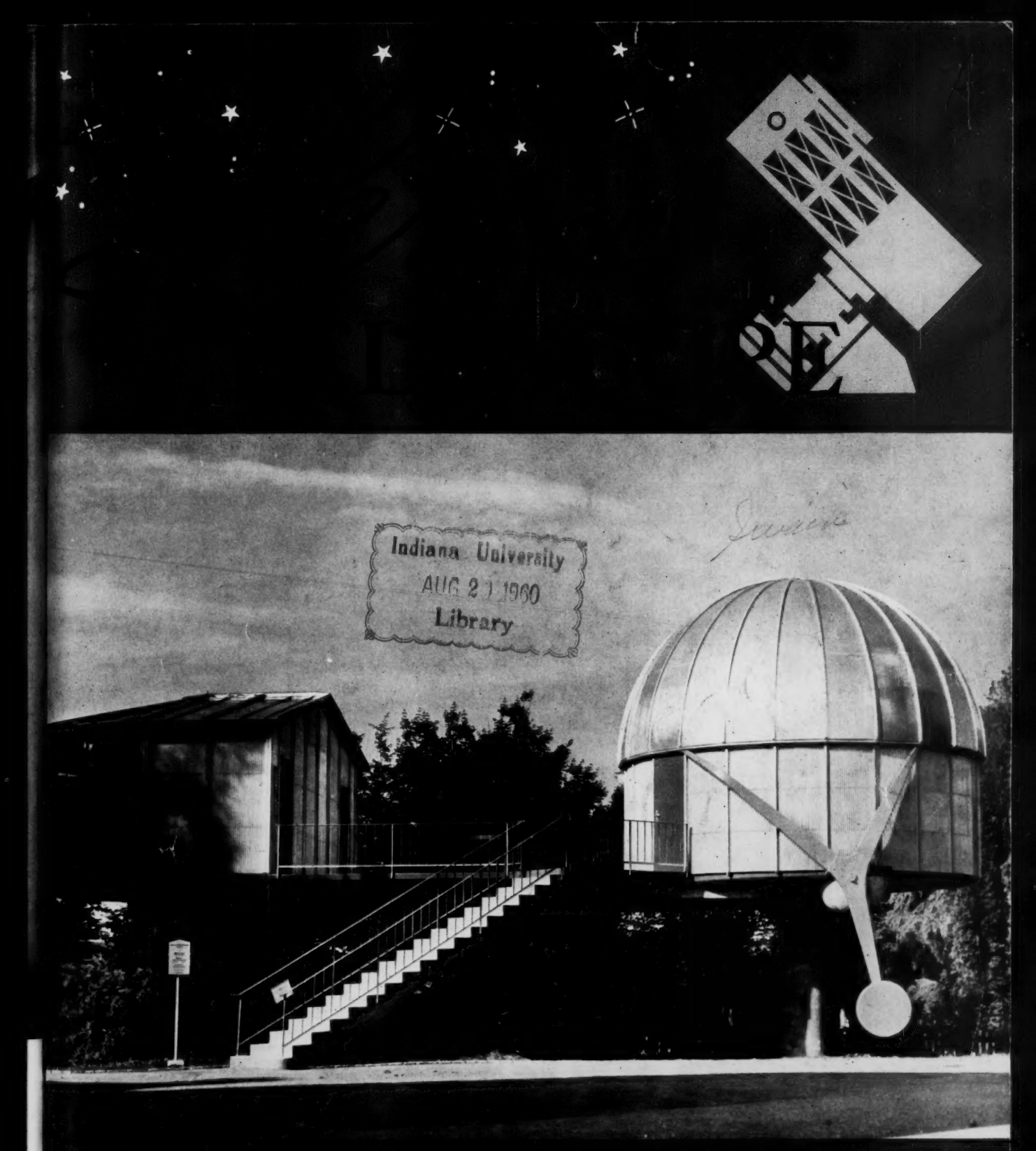

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TEACHING WITH A FECKER 10″ REFRACTOR

COMMENTS BY VICTOR GOEDICKE

Director,
Ohio University Observatory

"In teaching astronomy at Ohio University, I have found that the ten-inch refractor is the optimum design and size for our general student use. It is simple enough for elementary students to master with relatively few instructions, and yet large enough to provide optimum viewing under our city atmospheric conditions.

The fact that the elementary students use the telescope themselves, instead of being shown by the instructor, I believe to be an important factor in student interest in astronomy. At the Freshman or Sophomore level of student development, most students respond more readily to immediate experiences than to descriptions or even to supervised demonstrations. These first-hand experiences can then be followed up by the abstractions and generalizations which most teachers of astronomy consider to be the ultimate objectives of their instruction.

For more advanced students the telescope with its accessories provides opportunities for photographic and spectroscopic work as well."

This 10″ visual refracting telescope was designed and built by J. W. Fecker for the Ohio University Observatory. Requirements were for a telescope for student instruction and visual use.

ACCESSORIES AND FEATURES: Electrical sidereal drive, electrical right-ascension slow motion, manual declination slow motion, manual clamps in right ascension and declination, 3″ aperture wide-angle finder telescope.

For more information about this telescope or other telescopes to meet your specific needs, write

J. W. FECKER DIVISION
AMERICAN OPTICAL CO.
6592 Hamilton Ave., Pittsburgh 6, Pa.

Sky and TELESCOPE

CHARLES A. FEDERER, JR., *Editor*
JOSEPH ASHBROOK, *Technical Editor*

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Vol. XX, No. 3 SEPTEMBER, 1960

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Upper-Air Densities

A LITTLE over two years ago, L. G. Jacchia, Smithsonian Astrophysical Observatory, discovered small, erratic changes in the period of Sputnik II, and, later, in the periods of other artificial satellites. These changes were soon traced to fluctuations in the density of the atmosphere through which these objects were traveling. In addition, Dr. Jacchia demonstrated a very close correlation between this phenomenon and solar activity; on dates when 10.7-centimeter radio noise from the sun was strong, artificial satellites were decelerated.

At Bonn Observatory in West Germany, W. Priester and H. A. Martin have now studied the period changes of seven satellites, and derived from them long series of upper-atmosphere densities at three heights: 210, 350, and 660 kilometers. They have been able to separate two distinct types of density variation.

The first kind is connected with solar activity. The routine measurements at Berlin-Adlershof of the sun's 20-cm. radio emission provided a convenient index number for the activity. In the atmospheric layers between 210 and 660 kilometers, the air density changes in proportion to the intensity of this 20-cm. radiation. The German investigators believe that the physical cause of these density fluctuations may be the absorption by the upper air of either solar X-rays or far-ultraviolet radiation.

The second kind of change is a daily cycle, the density at a particular point varying with local time. The maximum density occurs between 1 and 2 p.m. For example, at 660 kilometers height, under average conditions of solar activity, the air density grows from 1.2×10^{-16} gram per cubic centimeter at 1 a.m. to 8.2×10^{-16} at 1 p.m. This is a sevenfold change occurring each day. These variations increase markedly with altitude.

Priester and Martin point out that, because of the large density changes, it is no longer possible to represent the atmosphere above 200 kilometers by a simple mathematical model. Instead, tables of the atmosphere's properties at different heights will have to be prepared for various levels of solar activity and various local times.

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Fraunhofer Lines and Heights in the Sun's Atmosphere

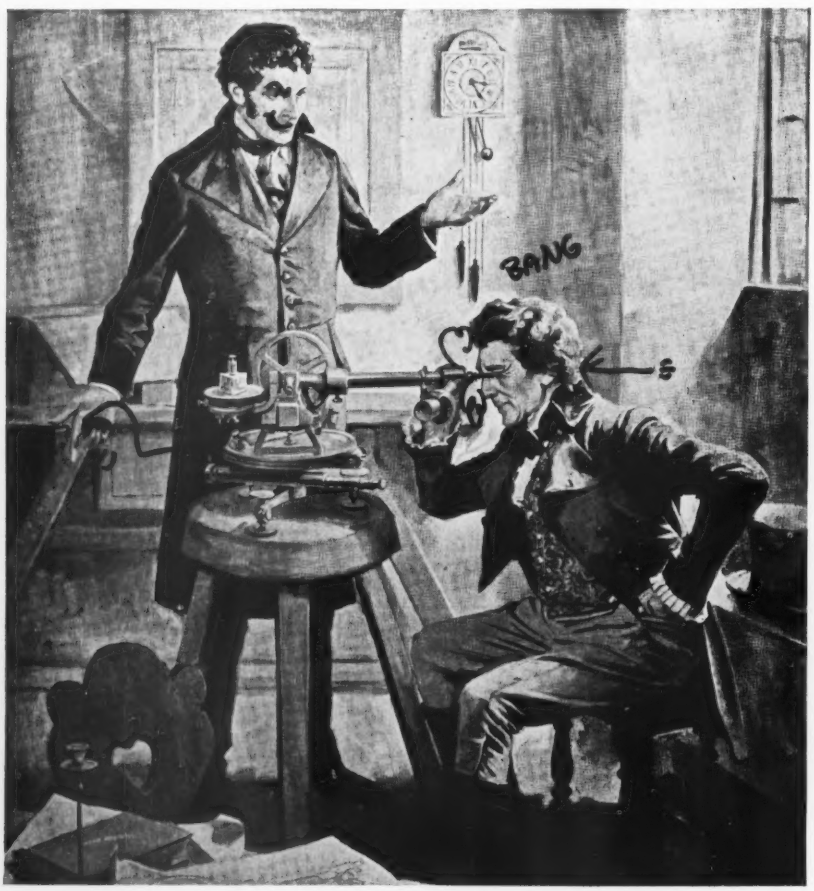
ORREN C. MOHLER, *McMath-Hulbert Observatory, University of Michigan*

ALL THE OBJECTS we see on the sun are three-dimensional, and measurement of the heights of their structural parts is essential to explain what is observed. Difference in level is just as important as extent along the solar surface, but we can measure the former only with great difficulty.

Existing methods use some form of highly monochromatic image of the sun. This is obtained most easily from the combination of a telescope and a spectroscope. Thus, measurement of differences in height is a special division in the art of solar spectroscopy. Although some techniques are fairly new, many procedures were discovered in the early days of astrophysics.

In 1815, Joseph von Fraunhofer discovered the dark lines crossing the spectrum of sunlight. This German optician had already observed the pair of bright orange-yellow lines, now known to come from sodium atoms, in the spectrum of light from a candle. Searching for similar lines in the solar spectrum, he unexpectedly found absorption features at the same positions as the emissions in the flame spectrum.

Fraunhofer made these discoveries more or less accidentally during the development of improved astronomical telescopes, but he explored the scientific importance of his unexpected results before exploiting them for practical ends. He diverted time and money from his business of making telescopes, and displayed enormous skill and insight in studying the spectral lines in the sun, planets, and stars. His investigations transformed the spectroscope from a toy that showed pleasing bands of colored light into an instrument for precise measurement, with which he founded spectroscopy as a quantitative science. Hence, although the dark lines traversing the solar spectrum had been glimpsed in 1802 by W. H. Wollaston, they are properly referred to as *Fraunhofer lines*. They have turned out to be of central importance in modern astronomy.



A recent painting of Joseph von Fraunhofer (1787-1826) demonstrating the solar spectrum to a friend with a spectroscope. Courtesy Bausch and Lomb.

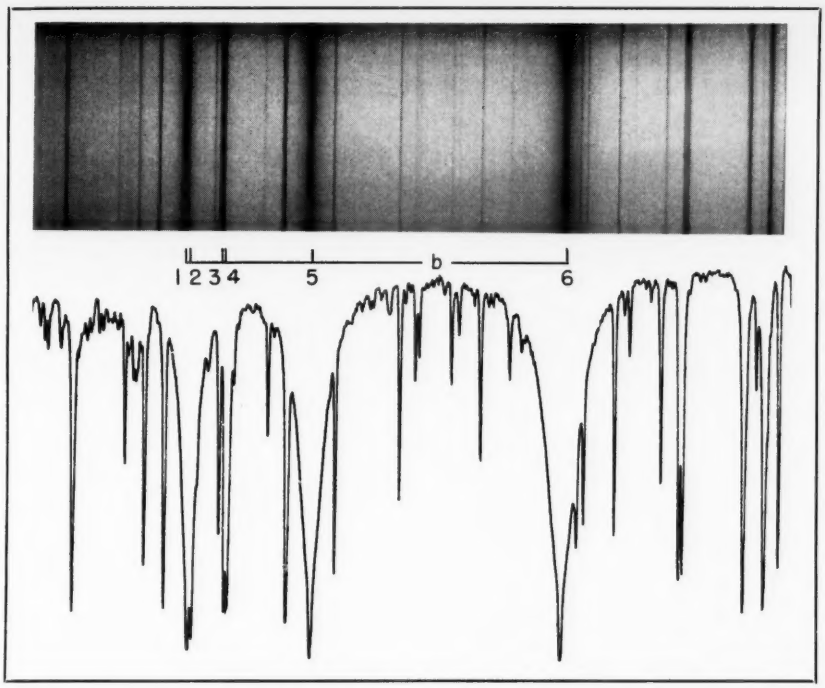
A complete theoretical explanation of the Fraunhofer lines, and particularly their variation with height in the solar atmosphere, will long remain one of the most interesting and baffling problems of solar physics. As an illustration of the complexities encountered, consider the short section of the sun's spectrum illustrated on the facing page.

The photograph shows the dark lines as they are seen in the focal plane of a spectroscope. This portion of the spectrum is near the wave length of the eye's maximum sensitivity to light, and in the spectral region where the sun radiates most of its energy. Such favorable circumstances facilitate the observation of these particular Fraunhofer lines by all principal methods: visual, photographic, and photoelectric.

The lower part of the picture is a mechanically constructed graph, made with the aid of a photoelectric cell. It is a record of the variation of light intensity along the length of the spectrum photograph.. The two broadest and blackest lines, **5** and **6**, and two close pairs of lines, **3** and **4**, and **1** and **2**, form a group that Fraunhofer described as follows: "At *b* there are three very strong lines, two of these are separated by just a narrow bright line. They are among the strongest lines in the spectrum." What Fraunhofer saw as two lines separated by a narrow bright one was actually the single line **5** and the four closely grouped features **1, 2, 3,** and **4**, which he saw as one.

A glance at the solar spectrum indicates that the Fraunhofer lines exist in all combinations of intensity and width. Some are narrow and very black at their centers; others are narrow and only slightly gray. Some wide lines are black, others gray. These are some of the complications that must be explained by spectroscopic theory.

The year 1959 was the centennial anniversary of Gustav Kirchhoff's publication of the first generally applicable laws of spectra. The German physicist based them on a long series of laboratory experiments, carried out in co-operation with the chemist Robert Bunsen. Kirchhoff was especially concerned with the spec-



A small section of a McMath-Hulbert solar spectrum, with an intensity tracing beneath it. The dark lines labeled 1, 5, and 6 are due to magnesium, and have wave lengths of 5167.3, 5172.7, and 5183.6 angstroms, respectively. Lines 2, 3, and 4 originate from iron, at wave lengths of 5167.5, 5168.9, and 5169.0.

troscopic detection and identification of chemical elements, and it was during the course of his work with Bunsen that the elements cesium and rubidium were discovered.

However, Kirchhoff's greatest contribution to solar astronomy was his masterful generalization now called *Kirchhoff's law*, which he applied to the analysis of the physical and chemical composition of the sun. This law states: "The ratio between the emissive power and the absorptive power for rays of the same wave length is constant for all bodies at the same temperature." With the aid of this relation, and the careful listing of its implications, Kirchhoff won general acceptance for four important conclusions about the sun.

First, in the orange-yellow part of the solar spectrum the coincidence of Fraunhofer lines with the bright lines in the spectrum of flames establishes the presence of sodium on the sun. Second, the source of the sun's light must be a substance, probably gaseous, at a very high temperature. Third, the part of the sun where the dark lines originate must be very hot, yet cooler than the main solar body. Fourth, the dark lines originate above the layers that are the sources of sunlight.

Up to the present, attempts to refine Kirchhoff's qualitative results of a century ago into detailed predictions of the properties of solar Fraunhofer lines have attained only moderate success. Efforts to solve the converse problem — deducing the detailed structure of the sun from the observed spectrum—have been reasonably rewarding, but they have encountered difficulties. The solar observations that must be explained by any adequate theory are exact and overwhelmingly abundant. Their high precision so limits the range of possible solutions that no theory satisfying all the measurements has been discovered. On the other hand, even though we may concentrate on explaining only a single spectral line and make the most reliable observations we can, the small deviations in the measurements are still too large to indicate a choice between competing theories of the formation of spectral lines, or between different theoretical models of the sun.

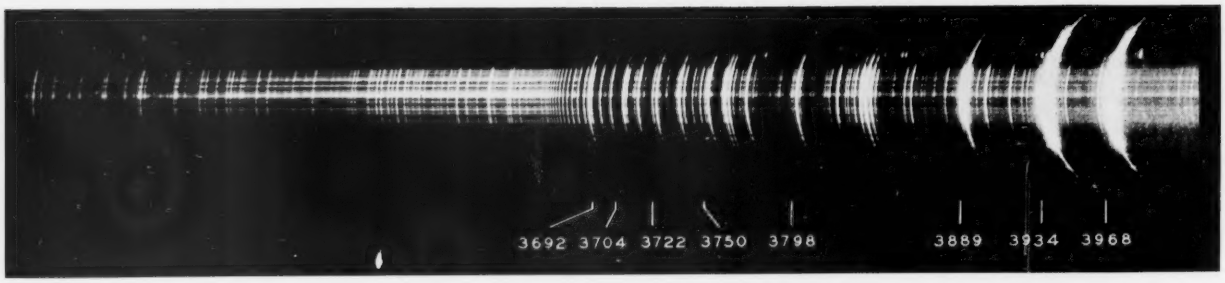
Solar spectroscopists generally agree that Fraunhofer lines are formed by several types of selective processes, acting together to withdraw radiation from particular regions of the spectrum, and followed by other processes that redistribute the extracted light throughout the entire spectrum. Although any particular line has a natural width that is determined by the characteristics of the atom from which it originates, in the sun the physical properties of the line-forming parts of the atmosphere play the dominating roles in making a line appear sharp or fuzzy, dark or only gray.

Some of the factors and their influences on the shapes of Fraunhofer lines are tabulated below. This summary shows that a given cause often will produce differing effects in lines from different atoms, or in different lines from the same atom. Measurements of carefully selected lines that are known from laboratory data to be especially sensitive to change in, for example, pressure, form the bases for computing some of the many numerical data needed for a complete description of the formation of the solar spectrum and its Fraunhofer lines.

However, many conclusions about the sun follow directly from spectral observations, without the aid of a completely satisfactory theory of line formation. For instance, the level at which a particular line originates can be defined from

FACTORS INFLUENCING ABSORPTION LINES IN THE SOLAR SPECTRUM

Physical Parameter	*Effect on Particles in Sun*	*Effect on Fraunhofer Lines*
Temperature	Random motions increase as temperature increases. Heavier particles move more slowly.	Broadening chiefly near the line center. Broadening inversely proportional to atomic weight.
Pressure	Collisions between particles increase as pressure increases.	Line broadens symmetrically. Some lines especially sensitive. Shifts in wave length.
Density	Collisions between particles increase as density increases.	Weak lines increase in strength more than strong lines.
Gravitational field	Confines particles to sun and produces gas pressures.	Lines are shifted to the redward of normal positions.
Radiation field	Collisions occur between particles and photons.	Lines are broadened.
Electric fields	Motions of free electrons and ions are hindered.	Broadening, or even splitting. Most effective for hydrogen and helium.
Magnetic fields	Motions of free electrons and ions are hindered.	Broadening or splitting of lines into components. Most effective for certain lines.
Turbulent motions	Particles move in eddies. Atoms move with speeds that are independent of their masses.	Broadening that is independent of weight of atomic source of line. Shifts of lines.
Convective motions	Produce streams in specific directions.	Displacement of lines.
Isotope abundances	Atomic species differing only slightly.	Blending of two different lines of same element.



Monochromatic images of the solar atmosphere appear as bright lines in this flash spectrum, obtained during the total eclipse of 1952. The longer arcs indicate higher levels on the sun. High Altitude Observatory photograph.

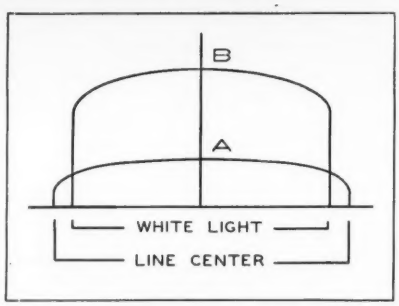
observing operations. Once we know the height of origin, we can use the spectral lines to deduce how physical conditions differ at various levels. Thus, determination of the level of origin for the Fraunhofer lines is extremely important for understanding solar flares, prominences, plages, and other features, as well as for constructing a theoretical model of the sun itself. The following are some of the more direct ways in which solar astronomers are trying to measure heights on the sun.

One fundamental spectroscopic method utilizes the geometrical circumstances of a total solar eclipse. During an eclipse, the moon acts like a sharp-edged circular disk, covering in succession the lower to higher layers of the sun's atmosphere just before totality begins, and uncovering the higher to lower layers as the total phase ends. For any instant, the relative positions of the sun's and moon's centers may be computed, and since their diameters are known with some precision, the fraction of any solar diameter that is covered or exposed can also be found.

A spectrum of the radiation coming from slightly outside the moon's edge originates at a known distance from the center of the solar disk, or at a known height, when the observation is made at very nearly the time of second or third contact of the eclipse. This flash spectrum is especially useful for studying the sun, since the moon blocks interfering extraneous light. But total eclipses are scarce events, and successful observation of them is at the mercy of weather. Other methods must be used to supplement the slow accumulation of data from eclipses and to check the results.

Many of these noneclipse methods are somewhat involved, and represent fairly long extrapolations from direct observation, but current techniques that use a spectroscope as a monochromator are relatively simple. They result from the great improvement in solar equipment during the past decade.

The modern spectroscopic monochromator can select extremely small portions from the spectrum. The distance between the two D lines of sodium pictured here

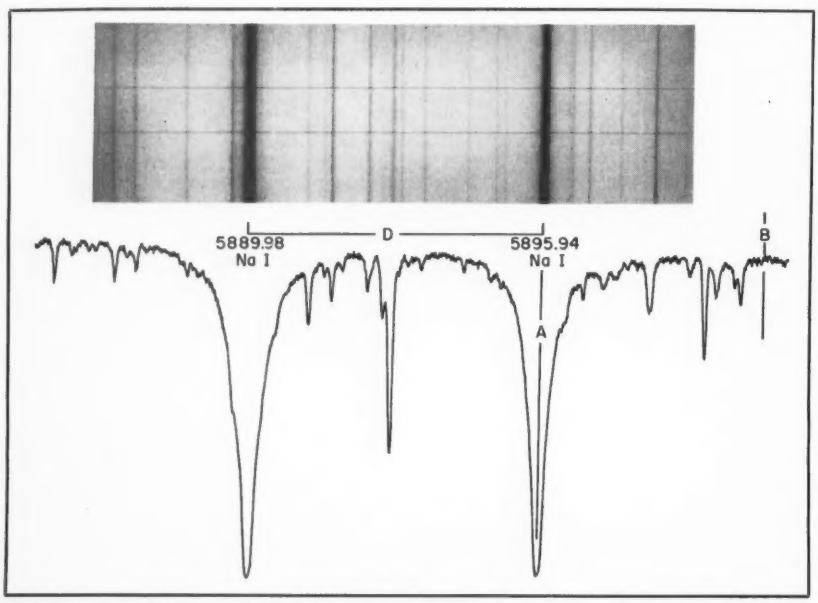


Intensity tracings across the solar disk made from the light within a Fraunhofer line "A" and in white light "B". The increased diameter indicated by "A" shows that the line originated above the sun's photosphere. "A" and "B" are marked in the tracing below.

is almost exactly six angstroms. With a good monochromator, we can select 1/600 of this distance. We can make continuous measurements at all points along a solar diameter with light from only the very center (**A**) of one of the D lines. As the point of observation travels uniformly along the solar diameter, an intensity curve like "A" in the diagram is obtained.

Curve "B" is for light from a neighboring part of the spectrum, labeled **B** in the tracing. Note that "A" is wider than "B," indicating that the diameter of the sun would be larger on a photograph taken in sodium light than on one made with the same telescope and light from a point in the spectrum where there is no Fraunhofer line. The difference in diameter is just twice the difference in height between the level of the solar atmosphere where the line originates and the region that gives rise to the light outside the line.

Instead of using photography, the diameter of the sun can be measured by recording the light intensity with a photoelectric cell, as the point of observation traverses a solar diameter, but this method demands close attention to several details. At the McMath-Hulbert Observatory, we use the McGregor solar telescope to measure the light variation along the sun's polar diameter. In this way, the effect of solar rotation on the position of the spectrum lines is automatically eliminated. If any other diameter is used, a tilting plane-parallel glass plate can readily be moved so as to introduce the desired correction,



The high dispersion and resolution of the spectrograph at the McMath-Hulbert Observatory of the University of Michigan are demonstrated by this spectrogram and photoelectric tracing of the intense D lines of neutral sodium, in the yellow part of the spectrum. Many delicate features are visible between them, although the D lines are separated by only 5.96 angstroms.

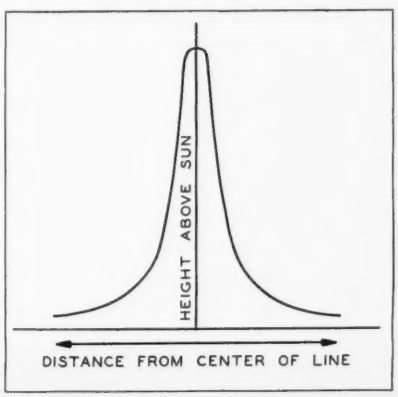
since the rotational shift varies linearly along any diameter. However, it is wise to avoid this complication, at least in the first trials of the method.

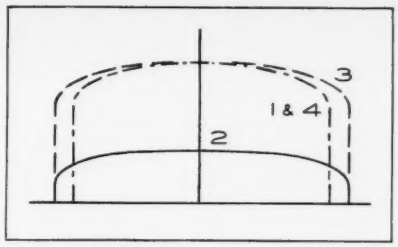
The observer adjusts the rates of the driving motors so that they produce a highly uniform and reproducible motion along the chosen solar diameter. The rate must not be so slow that unavoidable changes in atmospheric transparency, refraction, or focus can become significant during the time required to go from one edge of the sun to the opposite one. The sequence of operations is planned so that such changes in the instrument and the sky can be almost completely eliminated.

The following is a typical schedule (see sketch): 1. Make a trace of the intensity from limb to limb of the sun, using the continuous spectrum, that is, light free from any appreciable Fraunhofer line. 2. Similarly, trace the light from the center of a strong line, such as the Hα line of hydrogen. 3. Again trace the same line center, but with the gain of the amplifiers increased until the maximum deflection of the curve is the same as the maximum deflection of the curve obtained in the first step. 4. Record the limb-to-limb intensity in the continuum with the *gain* the same as in step 3, but with the *intensity* reduced by a filter so that the maximum deflection is the same as in steps 3 and 1. The observer then carries out the sequence in reverse order. Effects that change with time can thus be detected and appropriate corrections derived.

Ultimately, the observed curves must be corrected for blurring caused by imperfect seeing and faulty instrumental definition. After this is done, differences in the solar diameters defined by the curves indicate directly the difference in the atmospheric level at which the center of the line originates and the level represented by the continuous spectrum. The diameter associated with the trace of the continuous spectrum is the same as that of the solar disk seen in an ordinary telescope.

Only the stronger Fraunhofer lines that originate at relatively high levels can be studied by the method just outlined, because weaker ones are formed at heights smaller than the experimental error of the method. Unavoidable experimental





The schedule of scanning the sun, explained in the first column, gives four curves like these.

errors lead to uncertainties in height determination of slightly less than 1,000 kilometers. Since most solar lines are formed in layers not more than 500 kilometers above the sun's visible surface or photosphere, this is a serious limitation. However, for the very strong Hα line, the K line of ionized calcium, and the sodium D lines, the method gives interesting, consistent, and possibly trustworthy results.

So far, at McMath-Hulbert we have obtained height differences between the undisturbed spectrum and the centers of Hα, K, and the D_1 line of sodium. The heights are, respectively, 7,000, 7,600, and 1,200 kilometers. It is hoped that similar measurements can be made using light a short distance away from the line center, so that height calibration can ultimately be obtained for different points in a Fraunhofer line. A calibration of this sort should appear somewhat like the diagram below. With its aid we could place the interpretation of spectroheliograms, and similar monochromatic pictures, on a reasonably firm foundation.

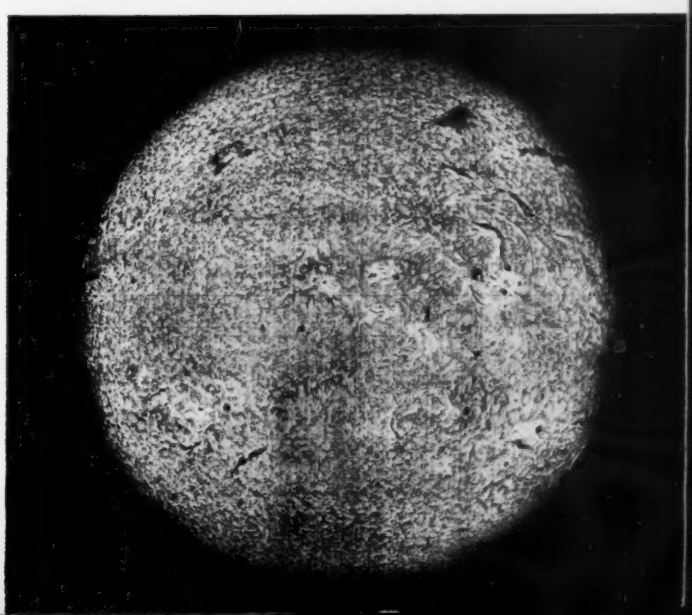
Usually, a monochromatic picture of the sun is considered to be a record of the various solar features in light of a particular wave length. It can be used to measure the relative positions of photographic details, as well as changes in position if we have a timed series of pictures. But there are serious ambiguities in the interpretation of these pictures, if anything more than a qualitative description is attempted. We are unable to assign a unique height to the features we see in them; that is, we cannot locate the features along the line of sight.

Consider a spectroheliographic picture made with a highly selective instrument. If light is used from the exact center of one of the strong Fraunhofer lines, for example Hα, we know from our height measurements that we can see only to within about 7,000 kilometers of the sun's surface. As the wave-length band used for the picture is shifted away from the center of the Fraunhofer line, the observed level moves closer and closer to the sun's surface.

This is a great advantage — to photograph easily at different levels in the solar atmosphere, even though the exact level is unknown. But difficulties may be introduced by the Doppler shift in the observed wave length that occurs as a group of atoms producing a Fraunhofer line move toward or away from the observer.

A spectroheliogram of the solar disk made with light a short way from the center of a Fraunhofer line shows two classes of objects. First, there are details at rest relative to the observer, located at a rather definite height above the surface of the sun. Second, there are features at other levels that become visible because the Doppler shifts of their line-of-sight motions are just right to make their radiations coincide with the off-center wave length under observation.

Troubles of this sort persist in all interpretations of highly monochromatic pictures, but they are especially disturbing in series of spectroheliograms made at very slightly different wave lengths within the same Fraunhofer line (see SKY AND TELESCOPE, April, 1960, page 339). If monochromatic pictures of this kind are combined with photographs of the spectrum and with the calibration of height across the line profile as described above, there is promise of significant progress toward a three-dimensional model of the active features on the sun.



Right: This Mount Wilson spectroheliogram shows the sun in the light of a single hydrogen line. At upper right, a large prominence appears dark, while across the sun's central regions are a number of bright plage areas associated with sunspots.

Left: When the sun is observed at a wave length that differs slightly from the center of a Fraunhofer line, we look to a greater depth in the solar atmosphere.

Members of the Astronomical Society of Switzerland built and operate this observatory for their city. Photograph by Ernst Burkhard.

A New Public Observatory in Switzerland

HANS ROHR

Astronomical Society of Switzerland

SCHAFFHAUSEN, Switzerland, has perhaps the world's severest case of "mirroritis." For in our town of about 30,000 inhabitants, more than 280 astronomical mirrors, ranging from 3½ to 12½ inches in diameter, have been ground since 1945, and about 150 of these are mounted in telescopes today.

Our local group of telescope makers, a section of the Astronomical Society of Switzerland, decided in 1954 to erect a modest municipal observatory, primarily for teaching and public nights. This facility was started in 1956, and officially opened this year on May 4th. The observatory is located where there is little light interference, although only about seven minutes travel from town.

A layman or school child visiting an observatory cannot be expected to orient himself by means of the tiny strip of sky that is seen through the narrow slit of a conventional dome. We felt, therefore, that designing a dome to expose a large part of the sky was our main problem. A pioneer member of our group, B. Bachmann, solved it in a novel way, using a pivoting arrangement that permits swinging the dome entirely clear of the observing platform, so that nearly the entire sky may be seen.

The swinging roof is more than 20 feet in diameter, but weighs only four tons, being made of light metal. Its pivot points are connected to the base by shafts set in reinforced concrete, and are offset about one yard from the central diameter of the building. Thus, as the simple hand-operated mechanism begins to move the dome, the front edge is lifted clear of the observatory wall before it starts to tip over to its position alongside the building. When closed, the cupola rests on thick rubber supports, and the overhang protects the observatory interior from the weather.

As can be seen in the front-cover photograph, the observatory sits at one end of an elevated platform, nearly 70 feet long, made of heavily reinforced concrete. Opposite the dome is a classroom, accommodating about 30 persons. This room is very convenient for informal talks and lectures when abrupt weather changes cancel observing sessions.

Our chief instrument is a 10-inch Newtonian reflector, having an internally reinforced nonrusting tube that can be rotated in a wide cradle. The polar axis is over three inches in diameter, and is turned by a conventional motor drive with differential and worm gear. Two additional motors permit fine guiding during photographic exposures. The clutch can be operated by hand or remote control.

The hour circle can be read to four seconds of time, the declination circle to two minutes of arc. The four-vaned adjustable spider for the secondary was especially designed to reduce torsion. Our eyepiece holder is a large chuck, to allow the attachment and centering of cameras and other accessories.

In place of the central spring or centering screw, conventional in Swiss telescopes, the mirror mounting has three adjusting screws with concentric springs. This simpler device puts the screws under tension, rather than pressure. Thus the force of the springs is self-contained, without strain on the base plate or mirror cell.

The pier upon which the telescope is mounted stands inside but does not touch the carrying column of the building platform. This hinders vibration of the building from reaching the instrument.

The view at the left shows the mounting of the Schaffhausen 10-inch reflector. At the right, the unusual tilting dome is partly opened. Both photographs are by Foto Bührer.

The total cost of the observatory, including the telescope and other equipment, was 66,000 Swiss francs (about $15,000). Over 200,000 francs would be needed to duplicate the installation commercially. In addition to help from club members, we received financial aid from industrial leaders, town and county authorities, and other benefactors.

We are fortunate that among our society members we have 12 volunteers to act as regular demonstrators. The public is invited on three evenings a week, with school and college groups on three other nights. During the first two months of operation, nearly a thousand persons, not counting school classes, visited the observatory. While there is no admission charge, we have a collection box for contributions, to be used exclusively for improvements to the observatory.

Astronomy is becoming very popular in our country. Ten years ago the Astronomical Society of Switzerland had but 390 members; now we have 1,400 — an impressive number in a country of only five million persons! We hope that our new observatory will help spread an even wider interest in the wonders of the heavens.

OPTICAL SOCIETY MEETING

The Optical Society of America will hold its fall meeting at the Somerset Hotel in Boston, Massachusetts, on October 12-14, 1960. In addition to inviting three speakers from the Soviet Union, the society has requested papers from A. Maréchal of Paris, E. Inglestam of Stockholm, and L. Bovey of Harwell, England. Seminars entitled "Teaching" and "Vision" will be conducted.

Further information about the meeting may be secured from Dr. Mary E. Warga, Optical Society of America, 1155 16th St. N.W., Washington 6, D. C.

This Month's Solar Eclipse

THE LAST of 1960's four eclipses will be a partial one of the sun on Tuesday afternoon, September 20th. Observers in Alaska, western Canada, the western United States, and northern Mexico can expect to watch the moon obscure a narrow part of the solar disk.

The accompanying map, which has been adapted from the *American Ephemeris,* will enable the reader to predict the approximate circumstances of the eclipse for his own locality. East of the heavy line running from Labrador to Alabama, no observations will be possible, as the eclipse begins after sunset. Within the large loop, reaching from the North Pole to Mexico, the sun will set before this eclipse ends.

Heavy dashed lines run roughly southwest to northeast, over the western part of North America, and are labeled with the Universal times of mid-eclipse. Cutting across them is a second set of lighter dashed lines, which indicate the half-duration of the eclipse. With the aid of this network, the beginning and ending times can be estimated for any place where the phenomenon is visible.

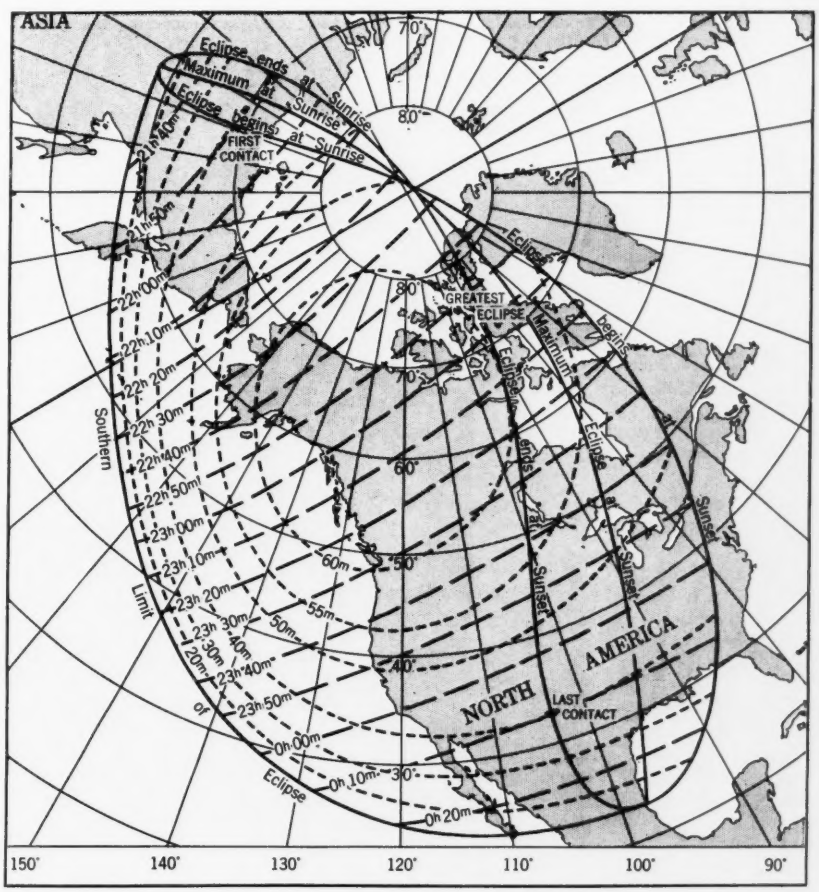
For example, consider the position at latitude 35° north, longitude 120° west, where the 120th meridian meets the California coast, near Santa Barbara. There the middle of eclipse is at $0^h\ 00^m$ UT of September 21st, and the half-duration is about 43 minutes. Hence the beginning and ending are at $23^h\ 17^m$ and $0^h\ 43^m$ UT, respectively, at that place. To obtain Pacific daylight time, deduct seven hours, giving 4:17 p.m. and 5:43 p.m. on the 20th.

Maximum obscuration will occur in Baffin Island, northern Canada, where 61.4 per cent of the sun's diameter will be covered by the moon at the middle of the eclipse. Farther west and south the value decreases, becoming zero along the line in the chart labeled "Southern Limit of Eclipse." Watchers in California should, therefore, expect to see only about 20- to 30-per-cent coverage.

One of the most satisfactory means of viewing the eclipse is by projecting a telescopic image of the sun on a white screen a foot or more behind the eyepiece, in exactly the same way that many amateurs observe sunspots. This method is safe, and permits simultaneous viewing by several persons. If the eclipse is viewed through a telescope, the aperture should not be more than two or three inches, and a very dense filter, preferably used with a Herschel wedge, is necessary to protect the eye.

Those watching the eclipse without telescopes should also use a very dark filter or unexposed film. A simple way to view a partial eclipse is to allow sunlight to enter a darkened room through a pinhole, which forms an image on the opposite wall.

Photography of the event is relatively easy if neutral density filters are used. Since the diameter of the solar image is only about 1/100 the focal length of the camera lens, a long-focus lens is advisable. Test photographs of the sun can be made in advance of the eclipse to determine the correct exposure and filter choice.



Western observers of this month's solar eclipse may use this diagram, adapted from the 1960 "American Ephemeris and Nautical Almanac," to predict the time and duration of eclipse at their particular localities. The moon's shadow will move from northwest to southeast across North America.

OBSERVING THE SATELLITES

Earth Satellites Now in Orbit

SO MANY artificial satellites are now circuiting the earth that it is not easy to remember all their names or even to guess their number correctly. Hence, the accompanying listing of the chief characteristics of 28 satellites aloft on August 1, 1960, may be useful. It has been compiled largely from data provided by the National Aeronautics and Space Administration.

Only those satellites sometime so well observed that their orbits were known have been included. Probably a 29th major object — 1959δ1, the carrier rocket of Explorer VI — is also circling the earth, but it has not been observed often enough for its path to be calculated. Not listed are various tiny bodies, such as the cast-off despin weights of certain satellites. Although some of these minor objects may remain up for centuries, they are rarely observed with present instruments.

For each of the 12 launchings that placed the satellites aloft, the dates and times are given in Universal time. All these objects were sent up from Cape Canaveral, Florida, except, by coincidence, those labeled *epsilon*. Of these, 1959ε2 (the capsule that separated from Discoverer V) and 1960ε1 (the cabin detached from Sputnik IV) share a further coincidence; neither was originally intended to be in orbit at this time! In both cases, the rockets that were to return them to earth were wrongly oriented when they fired.

The purposes listed for the individual payloads are somewhat arbitrarily selected, since most of the satellites have each carried several important experiments.

Explorer I (1958α) was the first successful American launching, following two notable Soviet firings that placed three objects in orbit in the fall of 1957. It was this satellite that gave the initial instrumental indication of the Van Allen radiation belts. Vanguard I (1958β2) was the first to succeed in a series of satellites intended as a major American contribution to the International Geophysical Year; it continues to return useful information from its tiny solar-powered radio. The Minitrack observations of this object have provided perhaps the most precisely known satellite orbit. It has given us important insight into atmospheric density, and has demonstrated that the earth's gravitational field is not exactly symmetrical around the terrestrial equator. Recent studies have detected the minute effect of the pressure of sunlight upon the motion of Vanguard I.

All of the five later 1958 satellites have long since fallen. Among them was 1958δ1, Sputnik III's carrier rocket, that was probably the most often observed astronomical object during its 202-day lifetime. An immense catalogue of nearly 100,000 optical and radar positions of it has recently been published by Space Track, almost 90 per cent of them obtained at Air Force stations. Most of the other observations in the catalogue were made by Moonwatch teams.

From last year's six successful Discoverer launchings, only the "wrong-way" capsule, 1959ε2, remains in orbit. Russia's Lunik III (1959θ), which photographed the far side of the moon, is presumed down. The other 1959 satellites are still aloft.

Vanguard II (1959α1) is the cloud-cover satellite whose data have been confused by its tumbling. The paddle-wheel satellite, Explorer VI (1959δ2), carried its varied array of instruments far out from Earth and returned to within range of terrestrial observers about twice a day. Despite repeated attempts to detect Explorer VI and its rocket carrier, there are no recent observations of either to provide current orbits and check the predicted effects of lunar perturbations.

Vanguard III (1959η) will be remembered by its peculiar conical appendage, and the "IGY heavy," Explorer VII, by its squat-spindle shape. Of 1959's satellites, only the latter is still transmitting.

The list omits Pioneer V (1960α) because it is moving around the sun rather than the earth. All of this year's satellites remain in orbit except Discoverer XI (1960ζ) and Sputnik IV's rocket (1960ε2), which returned to earth on April 26th and July 17th, respectively. During its relatively brief life, the latter was the brightest artificial satellite visible, a distinction that probably now belongs to 1960ε1, the "wrong-way" cabin. According to Space Track forecasts, two other fragments of the Soviet spaceship, 1960ε5 and 1960ε7, will shortly end their careers in space.

A new era in weather forecasting was ushered in by Tiros I (1960β2), but its television system ceased effective operation

CHARACTERISTICS OF ORBITING EARTH SATELLITES

	Satellite Name	*Launched* Date	*UT*	*Major Program*	*Shape*	*Length (in inches)*	*Diam.*	*Weight lbs.*	*Radio*
1958α	Explorer I	Feb. 1	3:48	Cosmic rays	Cylinder	80	6	31	Off May 23, 1958
1958β1	Vanguard I carrier	Mar. 17	12:15:41		Cylinder	48	20	50	
1958β2	Vanguard I	Mar. 17	12:15:41	Geodesy	Sphere		6.4	3.2	108.022 mc.
1959α1	Vanguard II	Feb. 17	15:54:28	Cloud cover	Sphere		21	23	Off Mar. 15, 1959
1959α2	Vanguard II carrier	Feb. 17	15:54:28		Cylinder	57	18	51	
1959δ2	Explorer VI[1]	Aug. 7	14:24:20	Van Allen belts	Sphere	29+	26+	142	Off October, 1959
1959ε2	Discoverer V capsule	Aug. 13	19:00:08	Recovery attempt	Tub	27	33	195	
1959η	Vanguard III	Sept. 18	5:29:45	Magnetometry	Sphere, cone	46	20	100	Off Dec. 11, 1959
1959ι1	Explorer VII	Oct. 13	15:30:05	Radiation balance	Biconical	20	20	91.5	19.9904 mc.
1959ι2	Explorer VII carrier	Oct. 13	15:30:05		Cylinder	60	6		
1960β1	Tiros I carrier	Apr. 1	11:40:09		Cylinder	72	24	50	
1960β2	Tiros I	Apr. 1	11:40:09	Weather patterns	Drum	19	42	270	107.997 mc.
1960γ1	Transit I-B carrier	Apr. 13	12:02:36		Cyl., nozzle	178	55	1283	
1960γ2	Transit I-B[2]	Apr. 13	12:02:36	Navigation system	Sphere		36	265	Off July 12, 1960
1960γ3	Transit I-B metal part	Apr. 13	12:02:36	Separation test	Plate		12		
1960ε1	Sputnik IV cabin[3]	May 15	?	Life-support test				5512	Off July 2, 1960
1960ζ1	Midas II	May 24	17:36:46	Launch detector	Cylinder	260	60	5000	Frequency secret
1960ζ2	Midas II fairing	May 24	17:36:46						
1960η1	Transit II-A	June 22	5:54:08	Navigation system	Sphere		36	223	54 mc., and others
1960η2	Transit II-A companion	June 22	5:54:08	Lyman-alpha	Sphere		20	40	108.00 mc.
1960η3	Transit II-A carrier	June 22	5:54:08		Cyl., nozzle	178	55	1283	

1. 1959δ1, the carrier rocket for Explorer VI, may never have been observed reliably; hence it is omitted from the list. Plus signs on the length and diameter of 1959δ2, Explorer VI, indicate that 20-inch-square paddles are attached. 2. The radio of Transit I-B may be reactivated later on solar power. 3. Total weight of Sputnik IV (including cabin) was 10,008 pounds. Objects 1960ε3-9 are fragments of the spaceship; they are included in the total of 28 satellites.

on June 17th. One of its tracking beacons continues to function.

The first experimental navigation satellite to attain orbit was Transit I-B (1960γ2), but its radio apparatus is now silent. Later, an attempt may be made to switch two of its transmitters to solar power. The second Transit satellite, 1960η1, continues to orbit remarkably close to its smaller twin, 1960η2. Their radios are still operating.

Even by radar, only infrequent observations are being made of the fragments of the Soviet spaceship numbered 1960ε3 through 9. The transmitter in the cabin itself, 1960ε1, is silent.

Largest and probably brightest of all American artificial satellites now circling the earth is Midas II (1960ζ1). The two Able-Star vehicles (1960β1 and 1960η3) are large enough to be faintly visible to the unaided eye under favorable conditions. All the rest are probably telescopic objects, and require detailed predictions of position for their observation.

Orbits of Current Satellites

MUCH information in compact form concerning the motions of the artificial satellites now in orbit is presented in the table on this page. These data, which are limited to objects whose paths are reasonably well known, have been adapted from elements provided by Space Track, the Smithsonian Astrophysical Observatory, and the NASA computing center.

The orbital elements of earth satellites are notoriously perishable, that is, liable to changes that make long-range predictions unsafe. For this reason, the numbers given here are valid for one particular epoch, 0^h Universal time on July 25, 1960. However, estimated rates of change of the three elements that affect the prediction calculations strongly are presented in the table.

In the second column, P is the anomalistic period, or the time in minutes required for the satellite to travel from the perigee point of its orbit around to that point again. In every case, this period is gradually shortening, as a result of interaction with the atmosphere. The rate of period change, P', is given in column three, expressed in minutes per day, and is an average rather than an instantaneous value. P' is among the least definite characteristics of a satellite's motion, and may easily change by several times its average value.

The apogee and perigee heights in miles are listed under H and h, respectively. These are heights based on the earth's equatorial radius of 3963.3 miles, and to get apogee and perigee distances from the center of the earth that value must be added to the tabulated figures. The semimajor axis of the satellite's orbit (not listed) is the mean of the apogee and perigee distances.

In the sixth column, i is the inclination of the satellite orbit, which is the angle between the orbital plane and that of the earth's equator. To specify completely the orientation of the orbit in space, a further quantity is tabulated as Ω in column seven. This is the right ascension of the ascending node, where the satellite passes northward through the earth's equatorial plane. As a result of the earth's oblateness, the node is shifting westward in every case, the daily change in Ω being listed as Ω'.

The ninth column specifies the argument of perigee, ω. It is the angle, at the center of the earth, between the ascending node and the perigee point, measured along the orbit in the direction of the satellite's motion.

Next is given the daily change, ω', in the argument of perigee. As the table shows, for satellites with small inclinations, the shift of the perigee is eastward (ω' positive), but for near-polar orbits the perigee is changing in the opposite direction. If a satellite had an orbital inclination of just 63.4 degrees, the argument of perigee would remain constant.

The last column tells us the location of the satellite in its orbit at the epoch, July 25, 1960, at 0^h UT. The quantity M is the fraction of the period that had elapsed at that time since the previous passage through perigee.

Beside giving a bird's-eye view of the nature of the orbits of the better-known current satellites, this listing furnishes the basic data needed for approximate predictions, at least for the immediate future. The listed satellites with high perigees all have well-known orbits, and for them the elements tabulated should provide fairly good predictions through September.

Since only six elements are needed to define an orbit at a given instant, and a seventh quantity is used to show the rate at which energy is lost to the atmosphere, it is evident that three of the 10 tabulated quantities are derived from the others. In calculating these the properties of the earth's gravitational field are considered. For this table only first-order effects that depend on the earth's oblateness were used; these suffice for all ordinary purposes. Recently, Dirk Brouwer of Yale University Observatory published a treatment that is complete to the second order.

MARSHALL MELIN
Research Station for Satellite Observation
P. O. Box 4, Cambridge 38, Mass.

EARTH-SATELLITE ORBIT SITUATION ON JULY 25, 1960, AT 0^h UNIVERSAL TIME

Satellite	*P*	*P'*	*H*	*h*	*i*	Ω	Ω'	ω	ω'	*M*
	min.	*min./day*	*miles*	*miles*	*deg.*	*deg.*	*deg./day*	*deg.*	*deg./day*	
1958α	108.03	−0.006	1195	214	33.21	197.7	−4.81	128.1	+7.18	0.531
1958β1	138.436	−0.00006	2680	408	34.25	230.4	−2.84	36.8	+4.15	0.794
1958β2	134.035	−0.00005	2448	405	34.26	75.7	−3.02	323.6	+4.41	0.695
1959α1	125.59	−0.0004	2047	349	32.86	146.7	−3.51	15.2	+5.28	0.685
1959α2	129.83	−0.0003	2281	346	32.89	261.9	−3.29	200.5	+4.95	0.531
1959δ2*										
1959ε2	99.52	−0.03	794	122	78.94	255.2	−1.32	338.6	−2.81	0.149
1959η	130.06	−0.0005	2321	318	33.34	295.3	−3.28	208.2	+4.88	0.947
1959ι1	101.25	−0.0003	670	346	50.32	35.6	−4.18	303.3	+3.40	0.737
1959ι2	101.14	−0.0003	667	343	50.30	34.4	−4.20	311.3	+3.42	0.536
1960β1	99.21	−0.0002	467	428	48.41	96.2	−4.55	226.4	+4.12	0.703
1960β2	99.22	−0.0001	466	430	48.40	96.2	−4.55	226.3	+4.12	0.450
1960γ1	94.51	−0.008	416	199	51.99	153.5	−4.73	251.6	+3.44	0.342
1960γ2	95.62	−0.003	444	237	51.28	159.8	−4.68	255.9	+3.57	0.887
1960γ3	93.62		384	177	51.29	136.0	−4.91	281.8	+3.75	0.511
1960ε1	94.01	−0.004	405	181	64.89	34.7	−3.30	66.8	−0.39	0.859
1960ε3	94.11	−0.002	419	173	64.89	35.3	−3.29	56.6	−0.39	0.217
1960ε4	94.0		408	176	64.89					
1960ε5	92.1		297	176	64.89					
1960ε6	92.1		294	176	64.89					
1960ε7	91.7		268	176	64.89					
1960ε8	92.3		305	176	64.89					
1960ε9	92.4		315	176	64.68					
1960ζ1	94.57		317	299	33.00	269.9	−6.43	333.2	+9.65	0.705
1960ζ2	94.20		303	291	33.00	268.6	−6.49	353.8	+9.73	0.418
1960η1	101.65		650	389	66.77	32.1	−2.56	212.6	−0.72	0.749
1960η2	101.65		658	382	66.77	32.1	−2.56	212.6	−0.72	0.759
1960η3	101.36		640	384	66.77	31.4	−2.57	211.1	−0.73	0.098

*Orbit uncertain

The abbreviations used in this table are: P, anomalistic period; P', rate of change of period; H, apogee height; h, perigee height; i, inclination to earth's equator; Ω, right ascension of the ascending node; Ω', motion of the node; ω, argument of perigee; ω', change in argument of perigee; M, fraction of period elapsed between time of previous perigee passage and July 25th, 0^h UT.

The Large Solar Telescope at Kitt Peak — II

ROBERT R. MCMATH and A. KEITH PIERCE, *Kitt Peak National Observatory**

AS TOLD last month, the world's largest telescope for observing the sun is now under construction at Kitt Peak in Arizona. Mounted on a tower some 100 feet high, an 80-inch plane mirror will reflect sunlight down a slanting shaft to a 60-inch concave mirror nearly 500 feet away. This will form a solar image almost a yard across, which can be photographed or studied with powerful spectrographs. We now continue the description of some design features of this novel instrument.

This very recent photograph shows the excavation at the south end of the solar telescope structure, where the 60-inch paraboloidal mirror will be housed. The view is southward along the optical axis from the floor of the observation room. Baboquivari Peak appears in the hazy distance.

HELIOSTAT MOUNTING

Our 80-inch heliostat mirror could be mounted in one of two basic ways:

1. On a fork, with two bearings, large worm wheel, and right-ascension driving mechanism; all this would be placed to the north of the mirror to permit the reflection of light south along the polar axis.

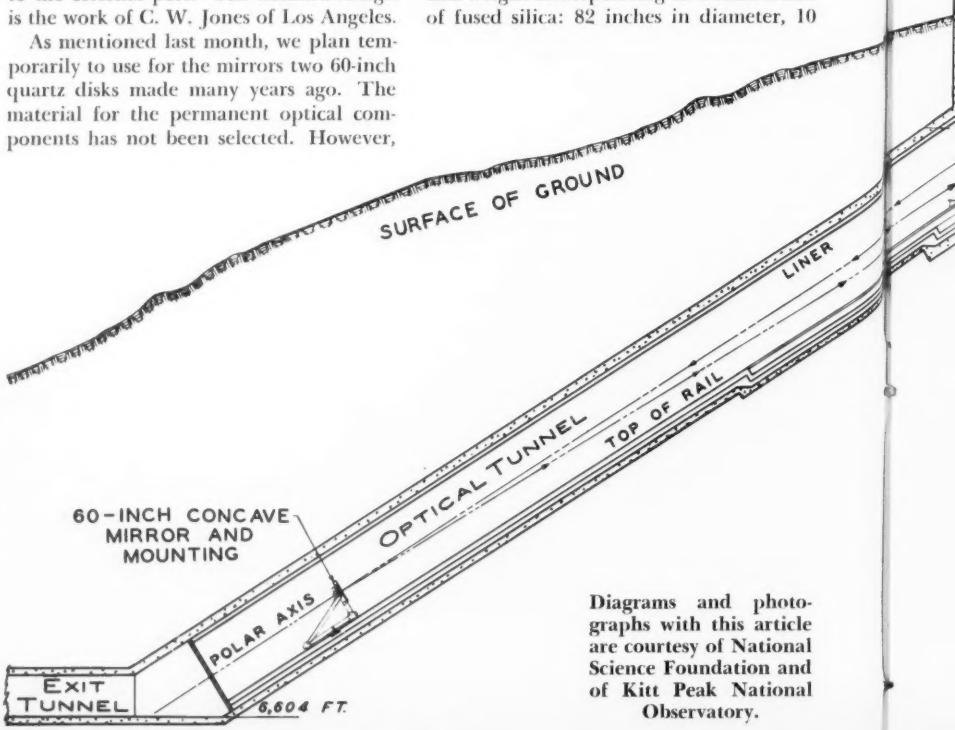
2. On a yoke or bobbin, with one bearing to the north and the other to the south of the heliostat mirror, as in the two-pier mounting of the Mount Wilson 100-inch telescope, but in this case requiring the southern bearing to be hollow so that light could pass through it to the 60-inch focusing mirror.

The fork mounting was rejected early in our design considerations, since it would require a large mass on the northern extension of the polar axis. This mass would therefore be *above* the level of the mirror and might influence seeing conditions; it would also present a large exposed area to the wind.

However, before a final decision was made in favor of the yoke type, we needed assurance from our engineers that the production of a precision worm gear without a hub or center was feasible. A ring worm gear, we were told, would offer no unusual problems in manufacture. In fact, having spokes or a thin web plate in the center of a large worm wheel presents very difficult casting problems that we avoid.

Having decided on the general form of the mounting, we next considered the mirror: its size, weight, and support structure or cell. The weight of these components determines the characteristics of the declination bearings and, in turn, the dimensions and weight of the yoke. The size of the hollow south bearing is governed by the diameter of the optical beam passing through it and, to a lesser extent, by the worm gear. The north-bearing size is determined by the load and the need to carry through it a number of wires and pipes. Finally, the support frame must rigidly carry the yoke and be adjustable to the celestial pole. The detailed design is the work of C. W. Jones of Los Angeles.

As mentioned last month, we plan temporarily to use for the mirrors two 60-inch quartz disks made many years ago. The material for the permanent optical components has not been selected. However, for design purposes we have assumed that the heliostat mirror, whether it be of ribbed steel, beryllium, Pyroceram, or fused silica, will have a maximum size and weight corresponding to a solid blank of fused silica: 82 inches in diameter, 10



Diagrams and photographs with this article are courtesy of National Science Foundation and of Kitt Peak National Observatory.

*Operated by Association of Universities for Research in Astronomy, under contract with the National Science Foundation.

inches thick, and 4,300 pounds in weight.

Such a mirror, if supported only around its rim, would sag 55 wave lengths of light simply from its own weight. Obviously, if we expect to hold the surface figure to ¼ wave length, a special support system is required. Furthermore, unlike the mirror of an ordinary reflecting telescope, this heliostat mirror will point downward much of the time. For example, at sunrise in the summer, the heliostat will have to reflect sunlight from the northeastern horizon to a direction 32 degrees below the south point of the horizon. To do this, the mirror will be tipped over on its face, pointing 28 degrees below the southeastern horizon. Yet, at noon in June, with the sun high on the meridian, the perpendicular to the mirror will point upward 25 degrees.

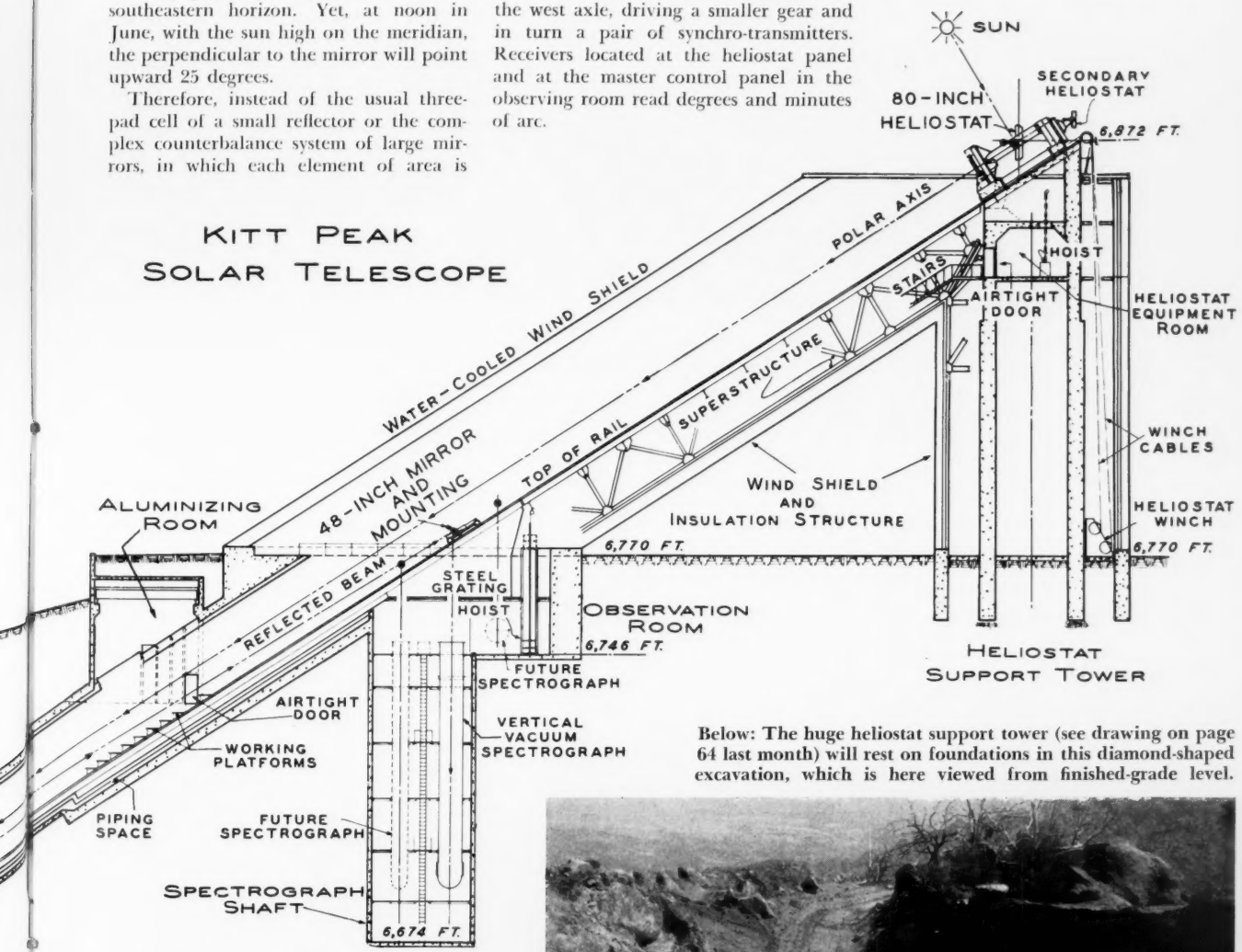
Therefore, instead of the usual three-pad cell of a small reflector or the complex counterbalance system of large mirrors, in which each element of area is supported both tangentially and normally to the surface, we have adopted another scheme. The weight perpendicular to the mirror's face can be perfectly supported by air pressure at the back, less than one pound per square inch being required with the mirror horizontal. This added pressure is less as the mirror is tipped, changing with the cosine of the inclination to the horizontal. It must be replaced with a slight vacuum when the mirror is facing downward.

As for edge support, a flat mirror will retain its flatness when tipped on edge if it is held hydrostatically around its rim by a tire that is filled with liquid of the same density as the mirror. Though the mirror becomes wedge-shaped in that position, its surface remains optically flat.

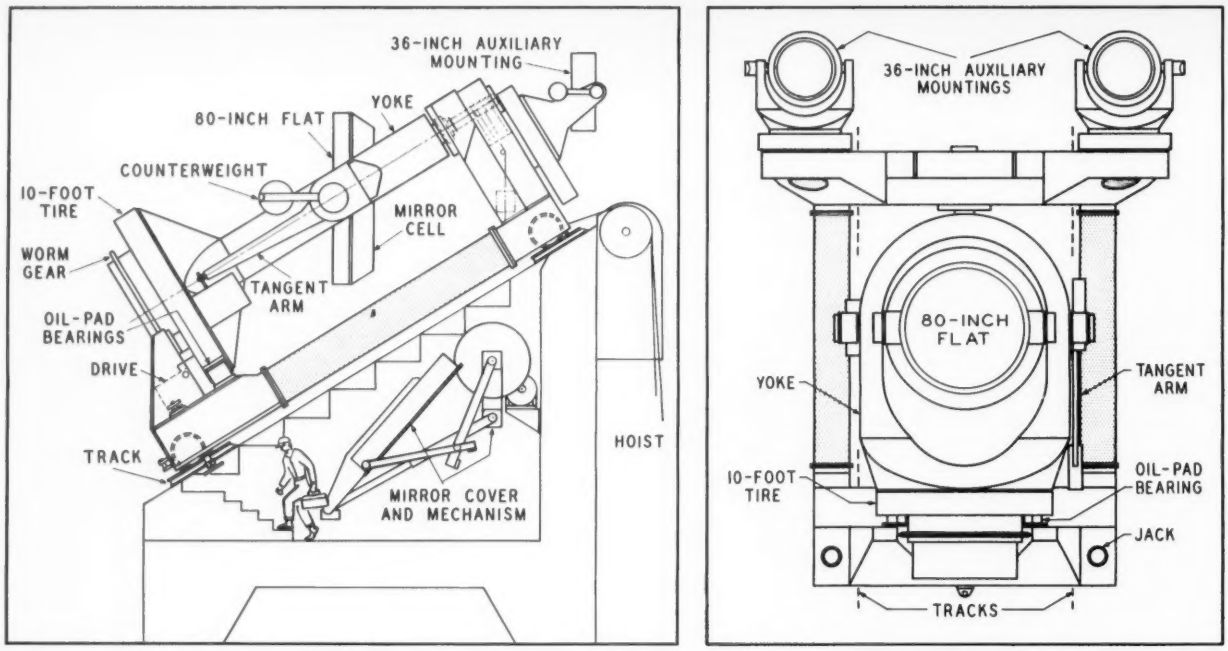
The mirror and cell are carried by large ball-bearing trunnions (18 inches outside diameter), located so their common axis is flush with the mirror face. The resulting unbalance of mirror and cell requires a pair of counterweights, one being labeled in the diagram. For indicating the mirror's position in declination, a pinion gear 30 inches in diameter is mounted on the west axle, driving a smaller gear and in turn a pair of synchro-transmitters. Receivers located at the heliostat panel and at the master control panel in the observing room read degrees and minutes of arc.

On the east side, for slewing the mirror to point it in declination, a 30-inch gear is driven by a worm and an air-operated motor. A tangent arm 94½ inches long is attached by air clamps to the worm gear to provide for slow motion in declination.

We debated the merits of a single large worm gear in place of the small gear with tangent arm. In the conventional astronomical telescope, use of a single large worm gear eliminates the difficult coupling problem between the slewing mechanism and the tangent arm. Also, an accurate declination-indicating system is



Below: The huge heliostat support tower (see drawing on page 64 last month) will rest on foundations in this diamond-shaped excavation, which is here viewed from finished-grade level.



These two drawings of the 80-inch heliostat mounting show it as seen from the east side (left) and from above. The jacks are used for polar alignment. Light from either of the 36-inch auxiliary heliostats must pass through the north pedestal, while the main 80-inch mirror sends its broad beam through the 10-foot tire southward to the focusing mirror.

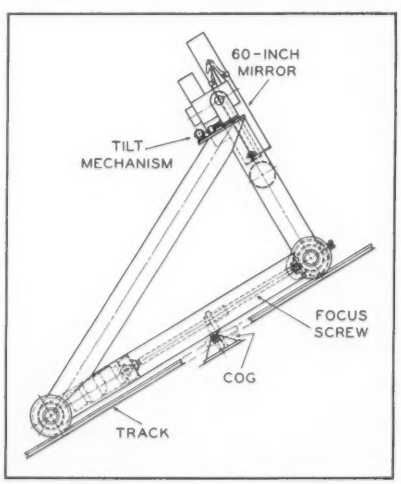
obtained directly from the worm gear's precision drive.

Despite these recognized advantages, in the design of the heliostat we preferred the complication of the tangent arm, because we could make it of long radius. Each small adjustment of the outer end of the tangent arm would thus provide a precise and very small change in the mirror's position in declination. This is important because of the doubled motion of the image caused by reflection from the heliostat mirror. We also felt that were we to put a worm gear 90 inches or more in diameter and its cover to one side of the mirror face, the free flow of air across the optical surface would be upset. Furthermore, the added mass would have to be counterbalanced and carefully temperature controlled.

A stress-relieved welded structure forms the 24,000-pound yoke. A hollow axle (eight inches inside diameter) at the north end carries an extension tube, around which is wrapped the right-ascension preload cable and through which electrical, water, and air leads are brought. The south end, which expands into a large ring bearing or tire 10 feet in diameter, is supported radially by two oil-pad bearings, while the 27,400-pound end thrust is resisted by two similar bearings on the south face.

When the right-ascension drive is started, there will be formed between the end-thrust pads and the south face of the tire an oil film 0.003 inch thick, which will cause a longitudinal displacement of the yoke and the north bearing. (A similar movement might be caused by differential expansion between yoke and base.) The simplest and most satisfactory way to provide for this motion would be to mount the north bearing in a thin flexure plate or diaphragm, thus allowing the north pedestal to move. However, since we plan to mount 36-inch auxiliary mirrors on the north pedestal, it must remain fixed in position. Therefore, we will permit a slight axial movement within the north bearing.

Meehenite-processed cast iron has been selected for the 720-tooth worm wheel. Each tooth is to be individually cut, hobbed, and shaved (or burnished) to a positional accuracy of 0.0002 inch. A hardened-steel worm, turning once in two minutes, will give the yoke a mean motion of 900 seconds of arc per minute. In some telescopes, the depth of engagement of the worm with the gear is governed by rollers riding on a concentric smooth surface. For the Kitt Peak heliostat, the worm and gear will have approximately 0.001-inch clearance when stationary. As the oil film on the pad bearing changes from zero to its operating thickness of 0.003 inch, the clearance will be substantially increased. However, if the right-ascension preload weight operates properly and the oil film thickness is constant, the drive will be accurate and without backlash.



A diagram of the 60-inch paraboloid's mounting, drawn nearly the same scale as those above. To move the frame along the track, the nut on the focusing screw engages one of several cogs.

Twelve sensitive limit switches, each with a micrometer adjustment, will be placed electrically in series with the right-ascension drive, so that if any one of them trips due to insufficient oil film the telescope drive will stop. About $1\frac{1}{2}$ gallons of oil per minute at 350 pounds pressure are required for the four bearings. It is of interest that the coefficient of friction for a ball bearing is about 0.002 while that of an oil-pad bearing is about 0.000001.

The telescope's drive must be remarkably precise yet very flexible. On the average, the sun appears to move across the sky at a diurnal rate of 900 seconds of arc per minute of time. But this uniform rate, that of the fictitious mean sun, is greatly modified for the true sun by refraction. This has its maximum effect at sunrise and sunset, displacing the sun a whole diameter at those times. For example, at a zenith distance of 85 degrees on June 21st, soon after sunrise, the rate in right ascension is 900 — 16.5 seconds of arc per minute of time, and in declina-

tion −8.7. Other factors affecting the sun's apparent motion are the inclination of the ecliptic to the equator and the eccentricity of the earth's orbit, but their effects are much smaller than that of refraction.

These changing rates, and various types of scanning motions desired by the observer, require that we superimpose on the uniform solar drive a variable system controlled either manually by the astronomer, or through a programmer such as punched tape, or by servomechanisms, with the actual superposition being accomplished by means of precision mechanical differentials.

The heliostat base frame will weigh 27 tons. Because of its size, 26 by 17 feet, and to solve a transportation problem, it will be manufactured in four parts: the north and south pedestals and the two side connectors (shaded in the diagrams). The frame carries four strong unsprung wheels and three jacks for polar adjustments. Also, rather than have separate supports for the proposed auxiliary optics, we have provided machined bosses on the north pedestal for mounting the 36-inch-aperture subheliostats shown in the drawings.

In accordance with our plan to maintain the surrounding air temperature on all surfaces exposed to sunlight, as discussed last month, the yoke face, gear covers, and support frame will be covered with panels having integral cooling channels or pipe. The hoist can move the heliostat along the track at four feet per minute. Its 20-horsepower motor drives a gear-reduction unit and two drums on which are wrapped a plow-steel cable $1\frac{1}{4}$ inches in diameter. Thus, the heliostat mirror can be transported to the aluminizing chamber whenever necessary.

Concave Mirror Mounting and 48-inch Flat

The mounting of the 60-inch concave mirror is relatively simple. It requires longitudinal motion for precise focusing, as well as up-down and east-west tilting for collimation. Mounting the mirror in gimbals permits scanning the sun's image and allows the proper positioning for easy removal of the mirror from its cell.

Recent experience at Mount Wilson with the tower telescopes shows that the quartz mirrors exposed to sunlight undergo focal changes of less than one-eighth of one per cent, whereas with pyrex mirrors the change amounted to one or two per cent. On this basis, we expect that our temporary quartz mirrors will have focal changes of about four to five inches. However, to accommodate other instruments and the focal planes of different spectrographs, we must provide about six feet of focus motion. Furthermore, to feed light to possible future accessories, the whole mounting of the 60-inch mirror must be movable 30 feet along the track.

The 60-inch mirror is supported by a stainless-steel band around its rim, and rests lightly back on a multiple-support system. Tilt motions are provided by tangent arms. Focus, over a six-foot range, is obtained by a motor-driven screw, whose nut engages a cog at one of several stations in the floor of the tunnel. One precision-ground V-shaped rail guides the focusing movement of the whole frame.

The third reflection of sunlight in the solar telescope takes place at the 48-inch optical flat located above the observation room, approximately 20 feet inside the 60-inch mirror's focal point. This flat can be tilted to direct the convergent beam to any spectrograph that may be used. Near the focus, the beam of light is only four times as intense as direct sunlight, hence we anticipate no great local heating there. It will be necessary, nevertheless, to receive the final image on a water-cooled surface, and to allow only that area of light necessary for spectroscopic observations to proceed to the slit.

Vacuum Spectrograph

The summer of 1955, warm and stable, gave excellent seeing at solar stations throughout the world. At Lake Angelus, Michigan, the new vacuum spectrograph of the McMath-Hulbert Observatory (Sky and Telescope, July, 1955, page 372) furnished beautiful spectra of solar granulation. The results tantalized us with the vision of a larger instrument of greater speed, fed by a large solar image.

Thus, the success of the Lake Angelus spectrograph has led us to plan a near duplicate of it for Kitt Peak. After a predisperser serves to prevent overlapping of the spectral orders, the light passes through a quartz window; it is collimated by a mirror and sent to the grating, located just below the slit and to one side. Part of the dispersed light is collected by one of two 16-inch concave mirrors, which forms an image on the photographic plate or photocell. The optical train will be inside a vacuum tank about 70 feet long and six feet in diameter, whereas the McMath-Hulbert tank measures 52 by four feet.

Planning the world's largest solar telescope has been a complex task. In addition to persons mentioned in the text of this article, W. W. Baustian, Ira S. Bowen, Orren Mohler, Bruce Rule, C. D. Shane, and many others have contributed ideas that have been incorporated into the instrument's design.

QUESTIONS... FROM THE S+T MAILBAG

Q. What are the magnitudes of Jupiter's four large satellites?

A. When Jupiter is at an average opposition, their visual magnitudes are: Io, 5.5; Europa, 5.7; Ganymede, 5.1; and Callisto, 6.3. But when the planet is far from opposition, they are considerably fainter, by as much as 0.9 magnitude when Jupiter is in conjunction with the sun.

Q. Are most lunar craters circular or elliptical?

A. The great majority are actually nearly circular, and appear so if located near the center of the moon's disk. In the vicinity of the moon's limb, perspective causes an elliptical aspect.

Q. Which planet is larger, Uranus or Neptune?

A. Uranus, for it has an equatorial diameter of about 29,600 miles, compared to 27,700 for Neptune. Both figures are somewhat uncertain because of the difficulties of measurement.

Q. What do the letters *c.p.m.* represent in the double star lists of Norton's *Star Atlas*?

A. They are an abbreviation for *common proper motion*, and are used to note that the stars of a pair appear to be traveling through space together.

Q. Do giant stars rotate quickly or slowly?

A. In general, more slowly than corresponding main-sequence stars.

Q. What are flare stars?

A. These are *M*-type dwarfs that have rare and very brief increases in brightness of between one and six magnitudes. Maximum brightness is reached in less than a minute, and the whole event lasts usually less than an hour. UV Ceti is a typical flare star.

Q. When is the next total eclipse of the sun visible in the United States?

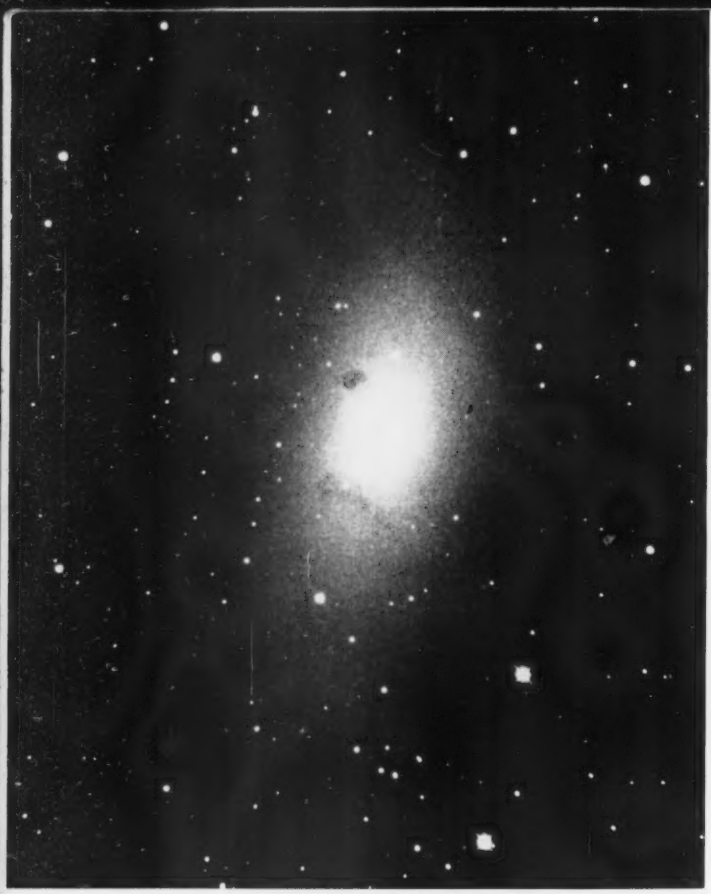
A. July 20, 1963. The central line extends from Alaska across Canada to Maine. The maximum duration of the total phase will be 100 seconds, in northwestern Canada. An early afternoon partial eclipse will be visible in the Northwest, whereas the time will be late afternoon for eastern watchers.

W. E. S.

BROOKHAVEN ACCELERATOR ATTAINS 30 BEV.

The alternating gradient synchrotron (AGS) at Brookhaven National Laboratory, described in the June, 1959, Sky and Telescope (page 446), was put into operation for the first time on July 29, 1960. For about an hour it produced a beam of protons with an energy of 24 billion electron volts, and then was stepped up to produce more than 30 bev., the highest energy reached by a particle accelerator.

Brookhaven scientists hope within the next few months to perfect the accelerator's adjustment so that its design energy of 32 bev. can be consistently attained. A similar accelerator near Geneva, Switzerland, in operation since late last November, works at 28 bev.



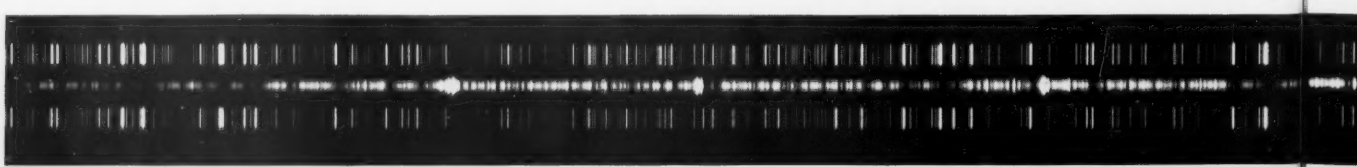
The elliptical galaxy NGC 205, a companion of the great spiral in Andromeda, photographed November 30, 1959, by N. U. Mayall, a 20-minute exposure on a blue-sensitive plate. The grainy texture of the outer parts indicates incipient resolution into stars of magnitude 21 and fainter. This galaxy was first resolved, in red light, by W. Baade with the 100-inch telescope at Mount Wilson in 1943. The system's longest diameter is about 16 minutes of arc.

Lick 120-inch Photographs—III

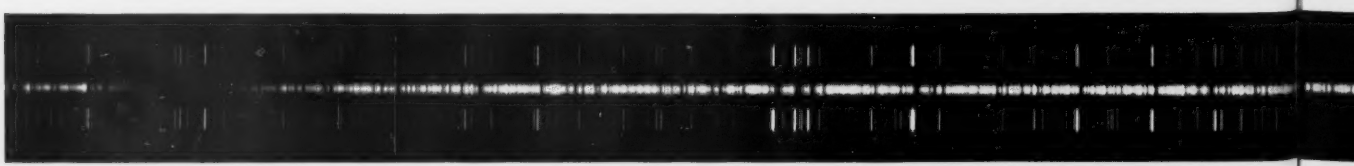
A PRIMARY PURPOSE of Lick Observatory's 120-inch reflector is stellar spectroscopy at very high dispersion. The telescope's effectiveness for this work is shown by the details in this spectrum of the long-period variable star R Leonis, taken on March 21, 1960. The giant *M*-type star was at magnitude 5.9, near its maximum light, during the 150-minute exposure.

Lick astronomer George H. Herbig used the coude spectrograph of the 120-inch, with a Babcock grating ruled 15,000 lines per inch over a 6½-by-8½-inch area. To obtain a larger scale, the second-order spectrum from this grating was used, being fed into a camera of 160-inch focal length. The slit width at the plate was 27 microns, and the final dispersion was 2.0 angstroms per millimeter. About 1,000 angstroms in the ultraviolet, violet, and blue regions of the R Leonis spectrum were recorded on two 2-by-10-inch plates placed end to end in the plateholder. Four-fifths of the resulting 20-inch spectrum is reproduced here. The Kodak 103a-O emulsion employed is most sensitive at these short wave lengths.

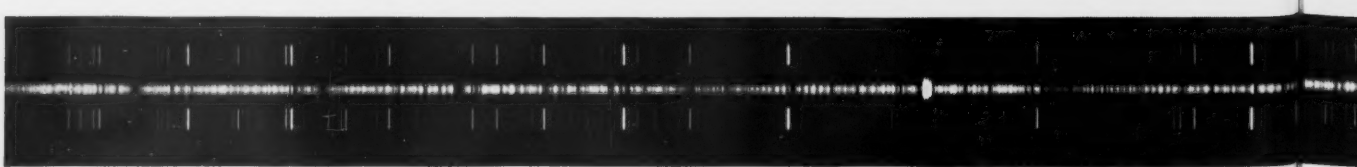
Along its entire length, the star's spectrum is flanked top and bottom by a comparison spectrum, in order to furnish a scale of standard wave lengths. The comparison spectrum was produced by light from a hollow iron-cathode discharge tube, containing neon gas at low pressure. This arrangement gives sharper lines, more stable in wave length, than does the iron arc usually used for this purpose.



R Leonis' spectrum in the ultraviolet from 3720 angstroms (left) to about 3865. Besides emission lines, a great number of absorption lines occur here, most due to metals. The adjoining section of the spectrum is on the facing page.

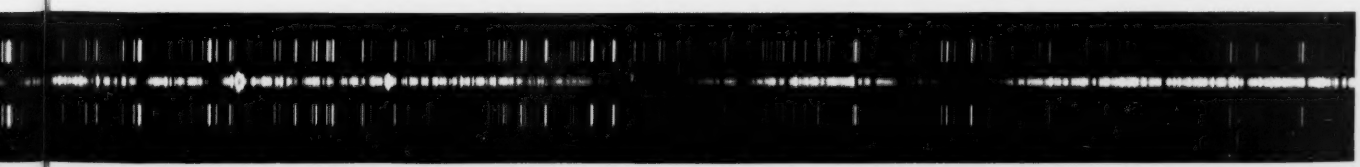


From 3950 to 4090 angstroms, overlapping the preceding part of the violet, including the calcium H line. Note that the iron absorption lines are displaced about 1/16 inch to the red (right) of the comparison lines — a Doppler shift.

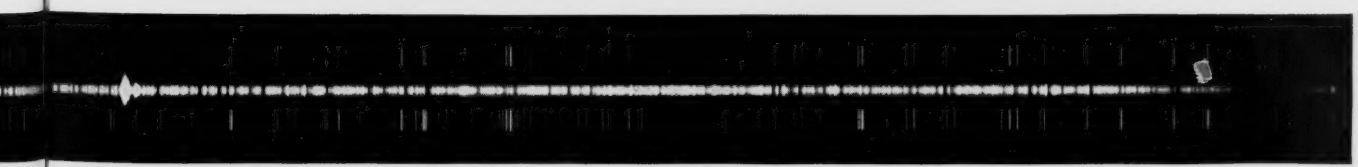


In the blue region, from 4240 to about 4380 angstroms, is another bright hydrogen line, H-gamma, 5½ inches from the left. It is a blend of several tightly packed components, as are the other hydrogen lines of R Leonis. The Doppler effect mentioned above results partly from the relative motion of the star and earth, partly from a pulsation of the star during the course of its light variation. The spectra of long-period variables undergo complex, little-understood changes.

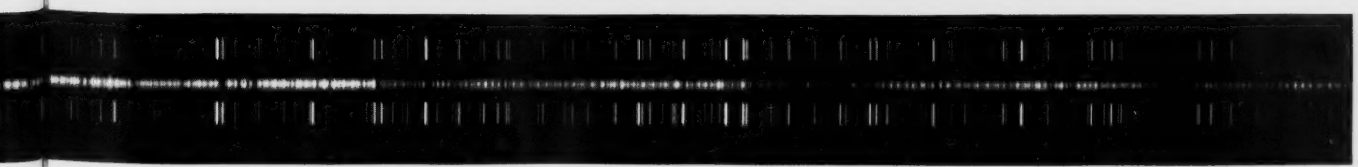
The intricate filamentary structure of the gaseous nebula NGC 6960 in Cygnus is well depicted in Dr. Mayall's half-hour blue-light exposure, obtained this year on June 26th with the 120-inch telescope under fairly good observing conditions. This is part of the western arm of the great Veil nebula loop, the whole forming an enormous expanding shell that may be the debris of a supernova explosion of perhaps 30,000 years ago (see "Sky and Telescope," January, 1958, page 116.) The motion of the nebulosity is upward in this picture. Compare the star-field richness in various parts of this photograph; the sparseness near top center and to the left indicates the existence of obscuring clouds of interstellar dust. The greatly overexposed bright star in the upper right is 4th-magnitude 52 Cygni. Previous photographs in this series from Lick Observatory appeared in July (pages 4 to 7) and August (pages 82 and 83).



From 3865 to 4010 angstroms. Measure from the right-hand end $2\frac{3}{8}$ inches to the very broad H line of ionized calcium, $4\frac{1}{4}$ inches to the K calcium line, and $6\frac{5}{8}$ inches to the intense emission line of hydrogen, H-zeta.



In this interval, from 4090 to 4230 angstroms, the strong bright line at the left is H-delta of hydrogen. To the extreme right, the broad dark line of neutral calcium at 4226 angstroms is very conspicuous.



The range here is from 4380 to 4525 angstroms. About $5\frac{3}{4}$ inches from the right-hand end, a sudden drop in the spectrum's intensity occurs, next to a regularly spaced extended pattern of narrow absorptions. These form a band of titanium oxide, a characteristic of M-type stars. Another band of this same molecule has its head $3\frac{5}{8}$ inches from the spectrum's right end. All photographs are courtesy Lick Observatory.

+++ Amateur Briefs +++

On September 12th, the Los Angeles Astronomical Society will begin its 18th year of monthly meetings at the Griffith Observatory and Planetarium. During the past three months, members have given 10 astronomy sessions for crippled children at two summer camps.

Tempus fugit. A former president of the Louisville, Kentucky, Junior Astronomical Society is the new head of the adult club in that city. He is James P. Bulluck, III, a recent physics graduate of the University of Louisville.

There are now 34 public observatories and more than 250 astronomical societies in Czechoslovakia, according to Dr. Oto Oburka, director of the recently completed Regional People's Observatory in Brno. The observatory is the clearinghouse for variable star observing in that country.

In May, some 25 juniors of the Seattle Amateur Astronomical Society were weekend guests of the Dominion Astrophysical Observatory in Victoria, British Columbia. After a look at Uranus through the 73-inch reflector, the youngsters camped on a nearby bluff for all-night observing.

When seeing conditions are good, members of the M31 club in Erie, Pennsylvania, arrange short-notice field trips by telephoning each other to meet at preselected sites.

Amateurs in Michigan and nearby states interested in meteor observing are invited to join the newly formed Michigan section of the American Meteor Society. Information is obtainable from Stephen P. Maran, University of Michigan Observatory, Ann Arbor, Mich.

Since March, the Astronomical League has received membership applications from six junior and four adult clubs, while five societies have dropped out of the organization. According to league president Chandler H. Holton, the AL is now comprised of 155 clubs (not including junior groups affiliated with regular societies) and 34 members-at-large.

From the *Galaxy* of the Kenosha, Wisconsin, Amateur Astronomers: "Here is a simple method for finding the angular diameter of the field of view with any eyepiece in any telescope. Pick out any prominent star on the celestial equator and allow it to drift across your field of view. As it moves from one edge to another it is timed. This time is multiplied by 15 to get the angular diameter in minutes and seconds. For example, if it takes one minute and three seconds for a star to cross the field, the diameter of your field of view is 15 minutes and 45 seconds."

The Burlington, Iowa, Astronomy Club wants to hear of project and program ideas to maintain interest among its members. Write to Jack R. Polson, 2214 Barrett St., Burlington, Iowa.

H. M. C.

Amateur Astronomers

Peruvian Amateurs Build Planetarium

THE Peruvian Astronomical Association was founded in Lima on August 15, 1946, by about a dozen amateurs. The society now has 300 members in six of the more important Peruvian cities.

Since our inception, we have followed two main courses: methodical astronomical observation and the popularization of this beautiful science. Our chief observing programs deal with sunspots and variable stars, with some attention to meteorological and seismological phenomena. To realize our second ambition, we set up an institute, giving weekly talks and lectures on what we call "Astronomical Fridays." A bulletin is also published, and several members give lectures on astronomical instruction to school teachers.

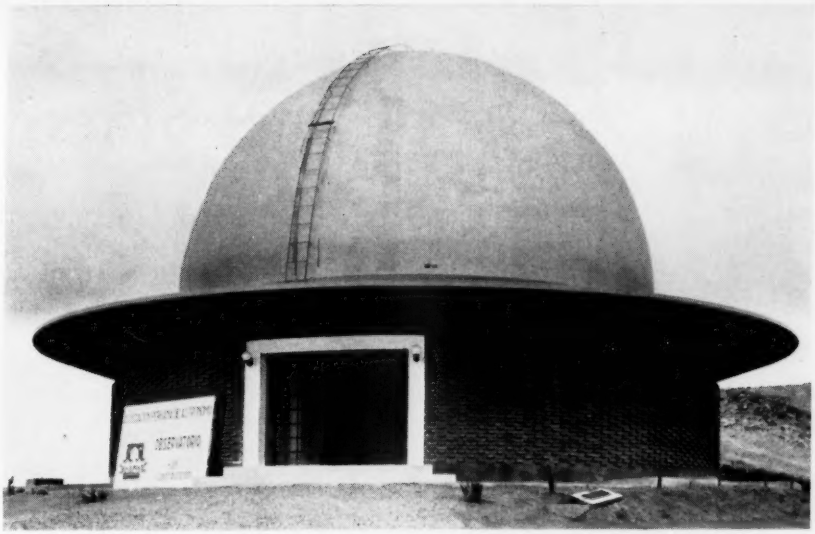
A suitable center for our institute, including an observatory, has been of primary concern. After much study and discussion, we decided in 1956 that a planetarium would be a good start in this direction, an observatory coming later. Commercial quotations were too expensive, so it was agreed to build the planetarium projector ourselves, relying on the technical skill and enthusiasm of Jose Castro Mendivil, an engineer and a founding member of the society.

The government generously donated land in Chorrillos, about nine miles south of Lima, overlooking the Pacific Ocean. Besides financial help from the government, we received funds from our members and their friends.

The planetarium building is cylindrical and two stories high. It is made of brick and reinforced concrete. The first floor has a lecture hall, a darkroom, rest rooms, and other conveniences. On the second floor, under a concrete dome 38 feet in diameter, is the theater chamber, which seats 120 persons. When necessary, standees can be accommodated in a circular aisle. Along the circumference of the dome is a silhouette of Lima's horizon as seen from the Campo de Marte, one of our principal parks. This montage can be illuminated to show the city at night.

The star projector is comprised of two aluminum hemispheres, 21 inches in diameter, separated by a six-inch space that contains electric and hand controls. On each sphere's surface are lenses and open-

Individual stars are projected through pinhole openings and special lenses in the Peruvian Astronomical Association planetarium.



The two-story planetarium building constructed by Peruvian amateurs.

ings that project the light from two small but very powerful bulbs. To achieve the desired effect, Mr. Castro made 340 lenses with diameters ranging from 25 to two millimeters, the smallest being put into place with tweezers!

The largest lenses are for such objects as Sirius, the belt of Orion, and the Pleiades. The faintest stars are projected through pinhole openings. The principal constellations and stars to the 6th magnitude can be shown, covering the entire sky.

This planetarium is the first one in South America that was designed and built solely by amateurs. In January, 1961, it will be visited by delegates attending the second convention of the Latin-American Astronomical League here in Lima.

VICTOR A. ESTREMADOYRO R.
Enrique Palacios 359
Chorrillos, Lima, Peru

JUNIORS IN NEW YORK AND RHODE ISLAND

On New York's Long Island, 24 juniors have set up the Bay Shore-Brightwaters Junior Astronomical Society. Its president is Richard B. Spivak, 517 Manatuck Blvd., Brightwaters, N. Y.

Last April, seven teen-agers formed the Rhode Island Stellar Society. Telescopes owned within the group range from 2½-inch refractors to a short-focus 10-inch reflector. The correspondent is Edward Turco, 2528 Cranston St., Cranston 9, R. I.

SPRINGFIELD, ILLINOIS

There are nine members in the Sangamon Astronomical Society. Further information may be had from Bart E. Schmitt, Jr., 308 E. Farley, Springfield, Ill., who is secretary-treasurer.

Among visitors at the planetarium dedication last spring was the Peruvian minister of public education, Jose Rubio (center). At the left is Augusto Cornejo, president of the Peruvian Astronomical Association; at the right, Jose Castro, who designed and made the projector. The pictures with this article were provided by the author.

THIS MONTH'S PROGRAMS

Metairie, La.: Pontchartrain Astronomy Society, 8 p.m., Metairie playground auditorium. September 9, J. W. Northrup, California Oil Co., "Some Ramifications of Relativity."

Washington, D. C.: National Capital Astronomers, 8:15 p.m., Commerce Department auditorium. September 10, Dr. K. A. Strand, U. S. Naval Observatory, "Astrometry of Faint Stars."

STELLAFANE MEETING

Tropical storm Brenda, passing northeastward across New England on Saturday, July 30th, caused torrential rains at Springfield, Vermont, where the annual get-together of telescope makers was in progress at Stellafane. More than a hundred persons gathered under the tent to hear the afternoon talks, but setting up of instruments was practically impossible, and the evening program was canceled.

MUSKEGON, MICHIGAN

A dozen amateurs answered a newspaper announcement of an astronomical get-together last March 9th, and have now formed the Port City Amateur Astronomers. The secretary is Mrs. Margaret Smith, 2014 Oak St., N. Muskegon, Mich.

HARRISBURG, PENNSYLVANIA

A different kind of group project was successfully attempted by the Astronomical Society of Harrisburg, Pennsylvania. For eight nights, members treated patrons of the Hotel Hershey to brief lectures, answered astronomical questions, and provided observing with telescopes. In appreciation, the hotel donated $25.00 to the club treasury.

NEW ENGLAND MEETING

Amateurs in the New England area are invited to an astro-assembly at 3 p.m. Saturday, October 1st, to be given by the Skyscrapers society at its observatory on Peeptoad Road in North Scituate, Rhode Island.

Prizes will be awarded for homemade telescopes and equipment. Additional information may be obtained from Mrs. B. Wray, R. F. D. Box 61, Assonet, Mass.

Conquest

Luna . . .
Pale and serene,
Trapped frozen world,
Tranquil, aloof. Your solitude
Shall end

And men
Shall make of you
A busy terminal . . .
A roadside stop to blaze their trail
Through space.

EDDIE-LOU COLE

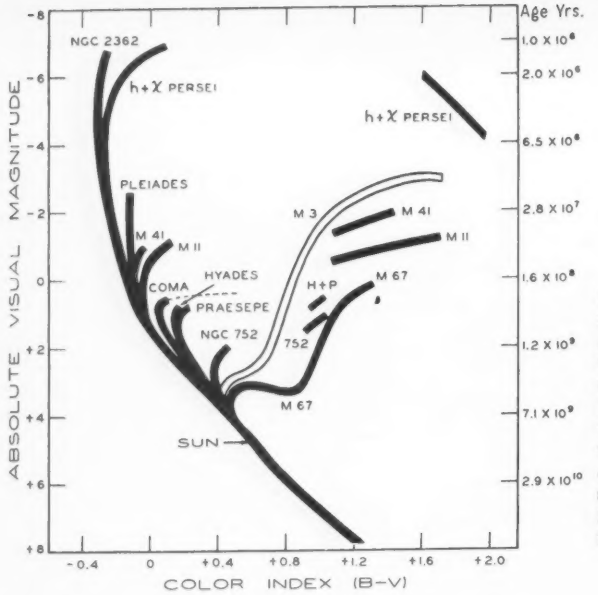


Fig. 1. In this 1957 color-magnitude diagram by Allan R. Sandage, the ages of stars in galactic clusters may be read on the scale at the right, valid for the upper end of each main sequence. The globular cluster M3 and the sun are included for comparison.

Ages of the Stars

OTTO STRUVE, *National Radio Astronomy Observatory**

THE STARS that make up our Milky Way system differ greatly in age. Very luminous hot blue objects, like Vega, are comparatively young; their enormous outflow of energy cannot have been continuing for more than a relatively few million years. Because such stars are observed in large numbers, the supply of them must be replenished, and some are being formed at the present time.

At the other extreme, the oldest stars are now believed to have ages of the order of 20 billion years, perhaps five times greater than the best estimates of astronomers a few years back. This far-reaching finding is based on studies by many scientists, notably Fred Hoyle in England, Martin Schwarzschild and Allan R. Sandage in the United States.

The break-through was made possible by a much improved knowledge of the thermonuclear reactions that are the sources of stellar energy and by a more refined understanding of the internal structure of stars. It became feasible to trace by calculation the manner in which a star evolves, as well as the time scale involved. Using a large electronic computer, today's theoretical astrophysicist can follow, step by step into the remote future or past, the changes of a model star in radius, luminosity, mass, and chemical composition.

If, then, the properties of suitably chosen model stars are compared with the observed characteristics of actual stars, much can be learned about stellar ages. Particularly suitable for this comparison are stars that belong to open clusters. The members of such a cluster are objects of similar ages, which have evolved at different rates, primarily because of differences in mass from star to star.

Three years ago, Sandage presented a paper on the color-magnitude diagrams of star clusters, at the Vatican symposium on stellar populations. His basic observational material is summarized in Fig. 1, which gives for each of 10 galactic clusters the relation between the absolute magnitudes and colors of its stars. The lower parts of the main sequences coincide, but for each cluster the upper end of the sequence turns to the right. The most luminous stars on these "stubs" are of absolute magnitude −7 in NGC 2362 and the Double Cluster in Perseus, but only about +2 in NGC 752.

Sandage gave the same cluster data in a different form in Fig. 2, where the vertical scale is stellar luminosity in units of the sun, and the horizontal scale is effective surface temperature. The dashed lines show the radii of the stars in terms of the sun's as unity.

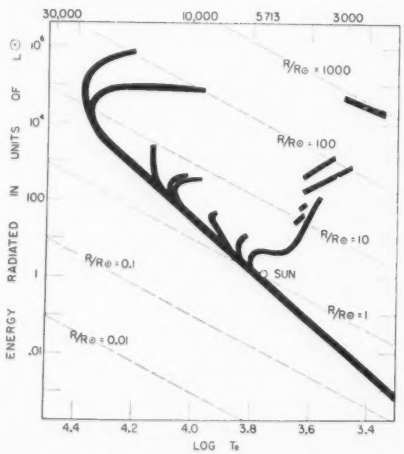


Fig. 2. The color-magnitude diagram as replotted with the horizontal scale converted to temperature in degrees Kelvin (top labels), and the vertical scale to intrinsic luminosity. The clusters to which different features refer can be found in Fig. 1. Hot stars are at the left and very bright ones near the top. The largest stars, with radii about 1,000 times the sun's, are in the Double Cluster in Perseus (upper right). From "Stellar Populations," Vatican Observatory.

Sandage told the astronomers gathered at the Vatican symposium: "Current ideas of star formation and subsequent evolution (due principally to early work by Opik, Schönberg and Chandrasekhar, Gamow, and later by Schwarzschild and his school) require that stars are formed from the interstellar medium and contract toward the main sequence. . . . The central temperature rises during contraction, until, at a certain critical value, thermonuclear reactions begin, contraction stops, and a stable star is born. The luminosity of the stable star depends upon the mass of the initial condensation. Because there is a mass distribution function for the initial condensation, stars are spread continuously along the main sequence at the time of stellar birth.

"The first result of the nuclear reactions is to convert hydrogen into helium in the central regions of the star. This causes a readjustment of the stellar structure so as to compensate for the increase in the mean molecular weight. Detailed computations of this structural change were first made by Schönberg and Chandrasekhar and later by many other authors. The general result is that the evolving star remains close to the main sequence until a critical fraction, q_c, of its mass has been exhausted of hydrogen, at which time the star rapidly expands and moves redward [rightward] in the color-magnitude diagram into the region of the yellow giants.

"These theoretical considerations find direct support in Figures 1 and 2 [Figs. 1 and 2 of the present article]. When a cluster has been in existence for a time T, all stars brighter than a certain luminosity will have exhausted the critical mass q_c and will have left the main sequence. Stars only slightly fainter than this limit will have exhausted a smaller fraction q_i [which is less than] q_c and will have evolved only slightly from their initial stellar structure on the main sequence. The details of the theoretical evolution explain rather well the observed change of slope of each galactic cluster main sequence near its termination point.

*Operated by the Associated Universities, Inc., under contract with the National Science Foundation.

AGES OF GALACTIC CLUSTERS

Cluster	*Constellation*	M_t	*Age in Millions of Years*
NGC 2362	Canis Major	<-7.0	<1
Double Cluster	Perseus	-7.0	1
Pleiades	Taurus	-2.5	20
M41	Canis Major	-1.5	60
M11	Scutum	-1.3	60
Coma	Coma Berenices	$+0.5$	300
Hyades	Taurus	$+0.8$	400
Praesepe	Cancer	$+0.8$	400
NGC 752	Andromeda	$+1.9$	1,000
M67	Cancer	$+3.5$	5,000

"The age of each cluster follows immediately if we identify the main sequence termination point with the stage when a star has exhausted q_c of its mass of hydrogen."

In this way Sandage obtained the cluster ages listed here. They can be read off directly on the scale at the right side of Fig. 1, at the level of the absolute magnitude, M_t, at which the upper end of a cluster's main sequence terminates. For M67 there is no gap between the main-sequence stars and giants, but +3.5 can be taken as the brighter limit for the former.

Fig. 3. The very young cluster NGC 2362 surrounds 4th-magnitude Tau Canis Majoris. This exposure of five-minute duration was taken with Harvard's 60-inch Boyden Station reflector on November 23, 1939.

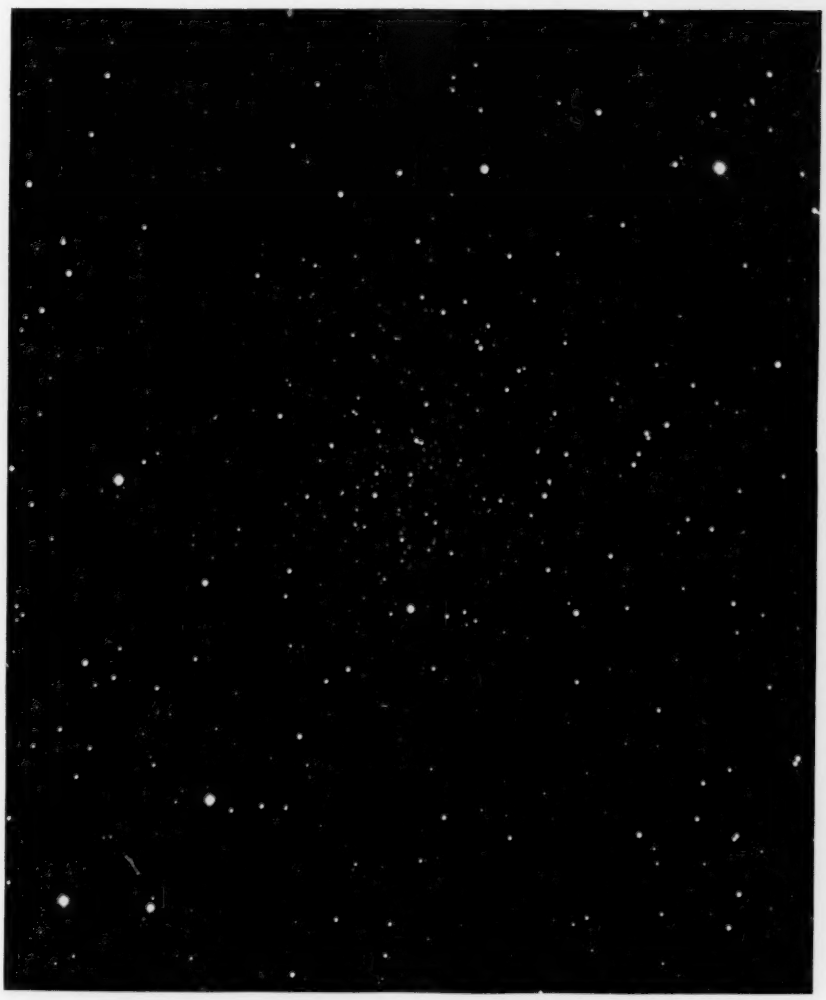


Fig. 4. The cluster NGC 188, from a 90-minute blue-light exposure with the Harvard 61-inch reflector, taken by Ivan King on July 10, 1948, is here enlarged to six minutes of arc per inch. The member stars are unusually faint for so large a cluster. Harvard Observatory photographs.

Thus the galactic cluster NGC 2362 in Canis Major (Fig. 3) consists of very young stars, less than a million years old, while M67 in Cancer has an age of five billion years, according to Sandage's 1957 work.

During the three years since, several important advances have been made. The time scale of stellar evolution has been more accurately calculated by several astrophysicists, most recently by Hoyle and his associates in England. These computations enabled him, in 1959, to revise the age of M67 upward to 9.2 billion years, and to find that the nearby subgiant star Delta Eridani may be as old as 15 billion years! Hoyle and J. Crampin also deduced an age of 50 million years for the Pleiades, although the member star Pleione might be even older.

On the observational side, Ivan King had called attention in 1948 to the odd open cluster NGC 188 (Fig. 4), noting that although it is 14 minutes of arc in diameter, its brightest stars are only about apparent magnitude 14. This cluster is in Cepheus, at right ascension $0^h\ 39^m.5$, declination $+85°\ 04'$ (1950), and is about 3,000 light-years distant.

In 1956, S. van den Bergh, at David Dunlap Observatory, noticed that the luminosity function (relative number of stars occurring at different levels of luminosity) of NGC 188 resembled that of M67. He therefore suggested to Sandage that NGC 188 might be as old or older than M67.

The California astronomer undertook a detailed investigation of the cluster in Cepheus, measuring the brightness of its stars in two colors on photographs taken with the Mount Wilson 60-inch reflector,

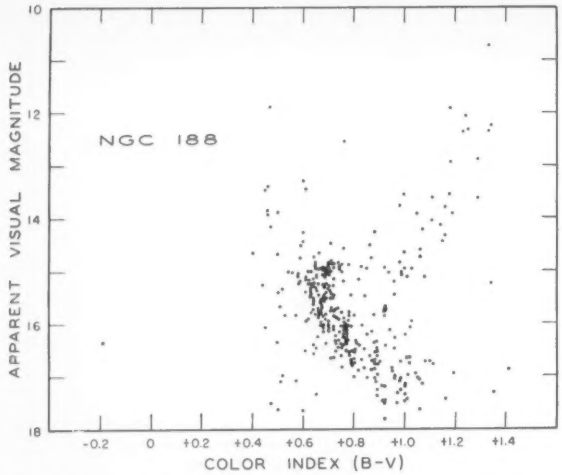


Fig. 5 (above). Each dot represents a star in the cluster NGC 188, plotted by Sandage in accordance with his measurements of its brightness and color.

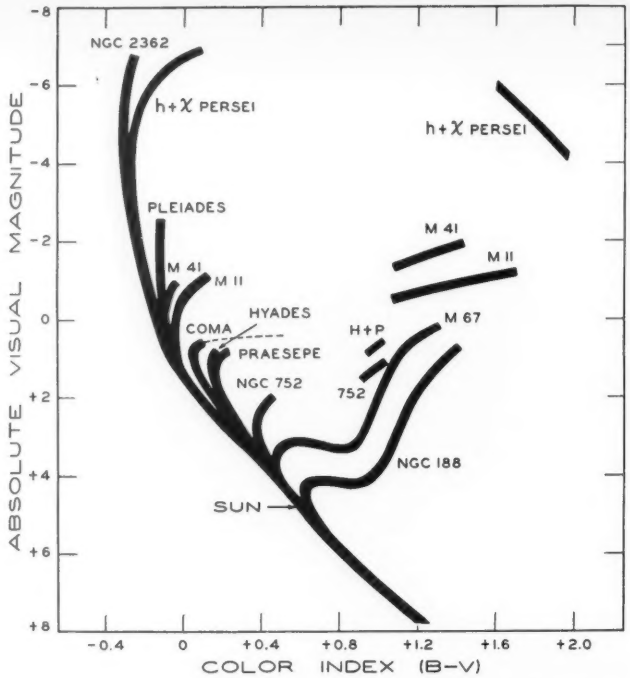


Fig. 6 (right) is like Fig. 1, but with the addition of Sandage's data for NGC 188. The position of NGC 188 in this diagram indicates its extreme age, greater even than that of M67. These diagrams are from Mount Wilson and Palomar Observatories.

in terms of sequences obtained photoelectrically with the 200-inch Palomar telescope. Figs. 5 and 6 are from the discussion he plans to publish in the *Astrophysical Journal*.

The first of the two is a color-magnitude diagram for NGC 188, from Sandage's own observations. Each point represents the apparent magnitude and the color index of a measured star. In Fig. 6, the data for this cluster have been added to Fig. 1.

There is a remarkable similarity in the color-magnitude patterns for M67 and NGC 188, but clearly the latter cluster is considerably older, because its turn-off point from the main sequence is at absolute magnitude +5 instead of +4. Using Hoyle's dating process that gave an age of nearly 10 billion years for M67, Sandage finds that NGC 188 is perhaps 24 billion years old.

Sandage cautiously remarks in a letter: "I personally do not much believe this large age and hope other theoretical people will compute additional models." But there is hardly any doubt that the *relative* ages of the galactic clusters are reasonably correct.

These new estimates by Sandage and Hoyle, of the ages of the oldest stars, run up to five times greater than the 5,000,000,000 years suggested not long ago for the entire galaxy. This longer time scale is consistent with some other kinds of astronomical data. For example, the age of the earth is fairly reliably known to be between four and five billion years; it is not unreasonable that the galaxy may be several times older. Furthermore, W. A. Fowler and Hoyle's recent calculations on the formation of chemical elements in the Milky Way system give an age of between 12 and 20 billion years.

Another argument can be based on the red shift of the galaxies. Present data indicate that the velocity of recession increases by 75 kilometers per second for each million parsecs of distance, though this value of the so-called Hubble constant is highly uncertain. On simplified assumptions, its reciprocal — 11 billion years — represents the lapse of time since the expansion started. But this age should not be taken too seriously, because the red shift of galaxy spectra is still not fully understood.

On the other hand, the very long time scale of the oldest stars contradicts some other results. In a discussion of Sandage's paper at the Vatican symposium, the Dutch astronomer J. H. Oort pointed out that only a few galactic clusters have hottest stars of spectral class *A*1 or later. Out of 70 clusters, 10 have stars between *O* and *B*2; the hottest stars of 51 are between *B*3 and *A*0; and only nine clusters have no stars earlier than *A*1. Yet, if we assume that clusters were born at a uniform rate during the last few billion years, there should be many more of them in the third group than in the first two combined, because cool stars evolve so very much more slowly than do hot ones.

Oort raised the following question: Can any galactic cluster resist for longer than five billion years the disruptive action of tidal forces exerted by other stars, cosmic clouds of dust and gas, and the galaxy as a whole? Even assuming that a cluster is dissolved only by gravitational interaction among its member stars,

Fig. 7. The open cluster Messier 11 in Scutum, from a photograph taken with the Palomar 48-inch Schmidt telescope. The east-west extent in this picture is one degree, and south is upward. According to Sandage in 1957, the age of this swarm of stars is some 60 million years. For observing information concerning M11, which is just visible to the unaided eye, **see page 155.**

Chandrasekhar found that the Pleiades will have broken up after three billion years. He derived similar maximum ages for other clusters.

Furthermore, if, as some astronomers believe, the internal motions of cluster stars exceed their velocities of escape (as they do in some stellar associations), these stellar groups would disintegrate even more rapidly, perhaps in a few tens of millions of years. Oort expressed his belief in "halfway long" ages of the order of 500 million years for the oldest open clusters.

Other evidence against extremely great stellar ages comes from S. S. Huang's very recent study of the masses of stars within 10 parsecs (32.6 light-years) of the sun. P. van de Kamp had listed these nearby stars which, with very few exceptions, are on the main sequence, being predominantly red dwarfs. There is a striking lack of stars with masses less than 1/20 of the sun's in this sample, although current ideas about star formation suggest they should be very numerous.

Why have so few such small stars been detected? Huang proposes that it is because they are not yet shining by thermonuclear reactions, but are still in the contracting stage of their evolution. Hence they would in most cases be too faint to be detected.

This would suggest that the age of the Milky Way is roughly equal to the time interval required for a star of about 0.08 solar mass, such as Ross 614B, to have contracted from a globule to a main-sequence *M* star. This time is about six to eight billion years. All stars of smaller mass would still be contracting, not having reached the main sequence. Huang also suggests that the emission-line *M* dwarfs (which become more numerous as we go from *M*0 to *M*6), the T Tauri variables, flare stars, and Haro-Herbig objects are all unevolved stars of this kind.

SOUTHERN ASTROGRAPH

Yale University has received a grant of $750,000 from the Ford Foundation to construct an astrographic telescope similar to the 20-inch Carnegie astrograph of Lick Observatory. This precision long-focus refractor is to be located in the Southern Hemisphere, probably in South America, and will be operated jointly by the observatories of Yale and Columbia University.

The main purpose of the new instrument will be to extend the survey of the sky that has been made at Lick, for the measurement of stellar proper motions with reference to the practically fixed background of very distant galaxies. About one-third of the entire sky cannot be observed from Mt. Hamilton, California, but will be very favorably located for the new instrument. The Carnegie astrograph and its program were described in this magazine for August, 1954.

NEWS NOTES

MASS OF M31

If its distance from us is known, the mass of a galaxy can be calculated from radial velocity measurements of the rotation of its central regions and spiral arms. The first work of this kind on M31, our neighbor spiral in Andromeda, was done two decades ago by H. W. Babcock. Since then, N. U. Mayall and several other astronomers have studied the rotation of M31 and determined its mass, some of the best observations having been obtained in recent years with radio telescopes in Holland.

At Yerkes Observatory, John C. Brandt has reviewed all this work and applied to the analysis of galaxy rotation curves the theory for the special case of a highly flattened system. In his report in the March *Astrophysical Journal,* he finds remarkable agreement among his and five earlier determinations, all of them giving for M31 a value between 350 and 400 billion solar masses, if the distance is taken as 600,000 parsecs (nearly two million light-years).

RADIO SOURCE STUDIES

Some of the strongest radio sources in the sky are Hercules A, Hydra A, and Centaurus A. Although the first two have been known for a decade, they have not positively been identified with visible objects, but their radio positions are near fairly prominent close pairs of galaxies. Centaurus A is identified with the peculiar galaxy NGC 5128.

All three sources have been recently studied at the radio observatory of California Institute of Technology, with one of the twin equatorially mounted 90-foot paraboloids in the Owens Valley. J. A. Roberts, J. G. Bolton, D. E. Harris, and B. G. Clark describe their work at a wave length of 31 centimeters in the February *Publications* of the Astronomical Society of the Pacific.

Earlier observations with interferometers at Cambridge, England, had given good right ascensions for Hercules A and Hydra A, but not declinations. To improve the latter, the California astronomers first determined the error curve of their giant instrument's declination circle, using as standards the intense radio sources Cassiopeia A (a peculiar nebulosity), Cygnus A (colliding galaxies), Taurus A (the Crab nebula), and M87 (a galaxy). The last of these four was further used to calibrate both right-ascension and declination dials on each night of observing.

Hercules A was observed on 14 separate dates, being placed at $16^h\ 48^m\ 43^s$, $+5°\ 06'.2$ (1950 co-ordinates). The new location rules out any connection with a pair of galaxies, but is only 1/10 minute of arc from a 19th-magnitude elliptical galaxy.

From observations on four nights, the earlier position was confirmed for Hydra A, adding some weight to its association with a close pair of galaxies.

Recent Australian observations of Centaurus A indicated that it spreads out for almost 10 degrees in declination. Bolton and Clark now find an extension toward the southeast from the southern part of this complex source, as well as a low-intensity trough between the central concentration and the southern region.

In the analysis of the Centaurus A observations, the effects of a strong radio "point source" coincident with the optical center of NGC 5128 were removed. The resulting map of radio intensities suggests that both extended sources, north and south, may be double, each consisting of a sharply defined and a diffuse object.

X-RAY SOLAR PHOTOGRAPH

Using an Aerobee-Hi rocket that rose 130 miles into the outer atmosphere, Naval Research Laboratory scientists have succeeded in taking the first X-ray photograph of the sun. A simple pinhole camera with an aluminum filter sufficed to make the picture, in a wave-length range of 20 to 60 angstroms. The rocket rotated slowly during its flight, smearing details of the photograph, but not obliterating its most interesting features.

The significance of this achievement was explained by Herbert Friedman of NRL at a symposium of the National Academy of Sciences and the American Geophysical Union. The sun appears as a bright, spotty coronal ring. Since the average temperature of the tenuous corona is about a million degrees, its gas is completely ionized, and the electrons move at very high speeds. When the electrons collide with heavy nuclei, X-rays are generated. The ring appears because the emitting region is thickest in the line of sight at the edge of the sun's disk. Virtu-

At the very short wave lengths of X-rays, the sun has the strange appearance shown in this rocket picture of April 19, 1960, taken at White Sands, New Mexico. Sharp dark and light markings are photographic defects. U. S. Navy photograph.

ally all X-ray emission is confined to a height about one-fifth of a solar radius above the disk.

At the time of the rocket flight, there was a bright calcium plage near the center of the sun, and it seems to have caused the bright area of X-radiation within the coronal ring.

STRATOSCOPE PHOTOGRAPHS STRUCTURE IN SUNSPOT UMBRA

The first photographs showing white gaseous dots in the center of a sunspot's umbra were obtained, by Stratoscope I, on September 24, 1959. Though bright specks in the dark umbra had been noted by visual observers long ago, little was known about them.

The picture shown here was taken by a balloon-borne 12-inch telescope 80,000 feet above the earth on the final flight in the Stratoscope I program (SKY AND TELESCOPE, January, 1958, page 112, and December, 1959, page 79). This project is under the direction of Martin Schwarzschild of Princeton University Observatory, and much time has been needed to analyze the vast quantity of data gathered by each flight.

Sunspots are more than a thousand centigrade degrees cooler than the sun's surface or photosphere; therefore, they appear dark against the bright solar disk. A special film was used to bring out the characteristics of the sunspot umbrae, while the penumbral filaments and photospheric granulations were overexposed and washed out.

The lifetime of the umbral dots is roughly half an hour, about the same as the gaseous filaments in the penumbra. The dots seem to be rising gases hotter than the rest of the umbra. Robert E. Danielson, a member of the Princeton research team, said, "While we do not yet know much about them, we know that they are very small — less than 200 miles in diameter. There is a possibility that they are convection cells somewhat like solar granulations, but strongly suppressed by the magnetic field of the sunspot. Much detailed analysis remains to be done before we can make conclusions about their characteristics."

Now under development is Stratoscope II, a 36-inch balloon-borne telescope system. It will be used primarily for observations of planets, stars, and galaxies. The work is being supported by the National Science Foundation, Office of Naval Research, and National Aeronautics and Space Administration.

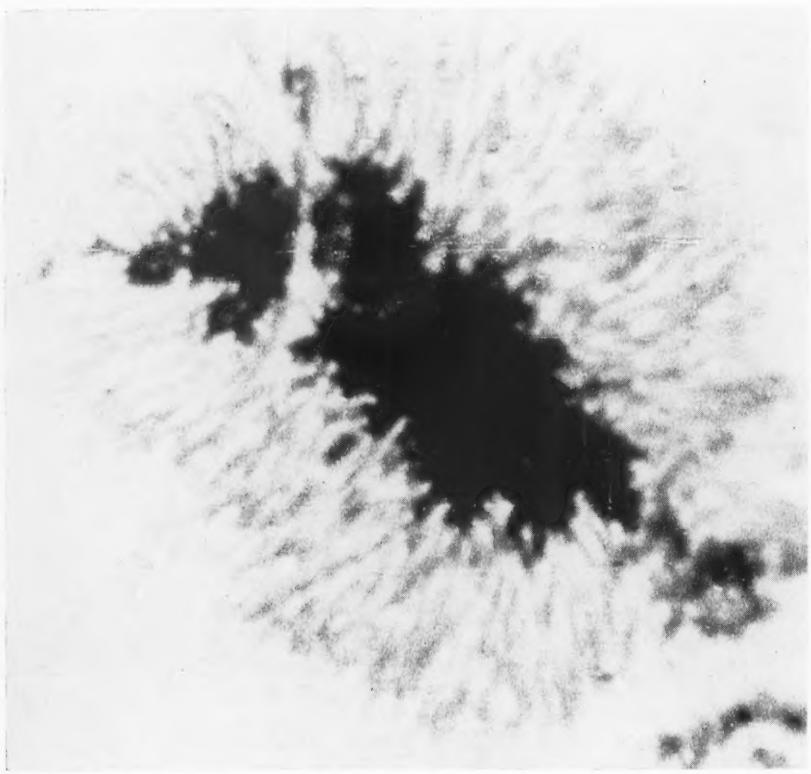
EARTH'S HYDROGEN CORONA

When the stratosphere was discovered many decades ago, indicating some stratification of the earth's atmosphere, it was suggested that the outermost atmospheric regions might consist mainly of hydrogen, the lightest element. But in 1950, when A. B. Meinel identified the radiation of the OH molecule in the atmosphere, the first indication was given that an atomic, rather than a molecular, hydrogen corona surrounded the earth.

R. Bates and M. Nicolet then pointed out that atomic hydrogen would be released at the rate of 10^8 atoms per second per square centimeter as sunlight dissociated water vapor and methane at an altitude of 80 kilometers. Diffusing upward, the hydrogen would become the atmosphere's principal constituent above 1,000 or 2,000 kilometers, it was suggested by S. Chapman in 1957.

Now, at Lockheed Aircraft Corp.'s missiles and space division, F. S. Johnson and R. A. Fish have deduced the properties of this hydrogen corona from nighttime Lyman-alpha observations and from the orbital decay of Vanguard satellite 1958β2. They believe that it is the hydrogen corona which produces the Lyman-alpha radiation observed during Naval Research Laboratory rocket ascents, rather than hydrogen atoms in interplanetary space (SKY AND TELESCOPE, July, 1958, page 445).

Reporting their results in the March *Astrophysical Journal,* the Lockheed physicists give a hydrogen concentration of 40,000 atoms per cubic centimeter at an altitude of 550 kilometers. This density drops to 1,000 atoms per cubic centimeter at 7,000 kilometers, and only 10 atoms at 36,000 kilometers.



Small white dots in the center of a sunspot are shown clearly in this Stratoscope high-altitude picture. The dark umbra's long dimension is roughly equal to the diameter of the earth. National Science Foundation photograph.

IN THE CURRENT JOURNALS

NUCLEAR PROPERTIES OF ANTINUCLEONS, by Emilio Segrè, *Science,* July 1, 1960. ". . . Recent important discoveries about beta decay and the neutrino now give a method for looking for antimatter which, while still impossible in practice, is sound in principle. . . . If we observe a star and from its astronomical characteristics can decide that most of its energy comes from a known cycle, as for example the carbon cycle, which is dominated by beta decays, we can see whether the antineutrinos coming from it are or are not of the same kind as the antineutrinos coming from a pile or from our sun by performing an inverse beta-decay experiment. If it should turn out that they are neutrinos — different from those coming from the sun — then the star is of antimatter."

THE COMING CONJUNCTION OF JUPITER AND SATURN, by C. H. Cleminshaw, *Griffith Observer,* July, 1960. "The giant planets, Jupiter and Saturn, are prominent in the sky almost all night now and they appear quite near each other. Jupiter rises about one hour before Saturn, which is now coming up as the sun goes down. As the months pass, Jupiter will catch up with Saturn, finally passing only one-fifth of a degree south of it on February 18, 1961."

GETTING ACQUAINTED WITH ASTRONOMY

THE PLANETS — EARTH

WHILE surveying the planets in this series of articles, we pause briefly at the earth, to consider a few of its astronomical aspects, although it is the subject of study by many branches of science besides astronomy.

Third in order of distance from the sun, the earth is a slightly flattened globe about 7,920 miles in diameter, moving in a somewhat elliptical orbit about the sun once in 365.2564 days, at an average distance of 93 million miles. It is similar in many respects to Venus and Mars, closely matching the former in size and having a day only 41 minutes shorter than the latter's.

In several ways, however, the earth is unique among the members of the solar system. It is a double planet, having a satellite fully a quarter of its own diameter, and it is the only astronomical body known to be mainly water-covered. The earth is further remarkable in having a surface layer rich in living organisms.

The ancients knew many simple observations and experiments that demonstrated important astronomical facts about the earth — observations still worth carrying out today by those getting acquainted with astronomy.

For example, that the earth is approximately a sphere will be graphically shown by the eclipse of the moon this September 5th. During the partial stages, the edge of the moon's shadow can be seen to be a portion of a circle, and the observer's recollection of past eclipses and his inspection of pictures of them will convince him that this is a general rule. The only geometrical figure whose shadow can always be a circle is a sphere.

The size of the earth can be checked with fair accuracy by a modern version of Eratosthenes' method, using an automobile. Drive 100 miles or more along a north-south road, and note the distance given by the mileage indicator. Determine the latitudes of the two ends of the trip, for example by observing noon altitudes of the sun with a bubble sextant, or by measuring the elevation of the pole star at night. Then the circumference of the earth is in the same proportion to the distance traveled as 360 degrees is to the latitude difference. Ralph W. Crowder, Neodesha, Kansas, reports an excellent result from this experiment.

The westward march of the constellations across the sky each night is a striking indication of the earth's rotation. Many an amateur has recorded the trails of circumpolar stars by a long exposure (like the one on page 146) with a stationary camera pointed toward the celestial pole. This pointing does not have to be done accurately, as the circular star trails themselves define the actual pole position.

Strictly speaking, such a picture does not prove it is the earth rather than the sky that turns. This proof is furnished by the comparatively modern Foucault pendulum experiment (described on page 144 of the January, 1960, issue). Another test is provided by the eastward deviation of a falling body, such as a lead pellet dropped down an elevator shaft. Because the earth is rotating, the top of the shaft is traveling eastward with a greater velocity than the bottom. Simple in principle, this experiment requires much care because of the smallness of the deviation — only 0.17 inch for a drop of 100 feet at latitude 40° north.

The shape of the earth's elliptical orbit around the sun can be determined easily with the aid of a small telescope and a stop watch. The sun should be viewed by projecting its image through an eyepiece onto a white screen, or a Herschel wedge used in conjunction with suitably dense filters to protect the observer's eye. Record the time required for the sun to drift past a crosswire in the field of view of the stationary telescope. The solar diameter, measured in this fashion, will be a maximum about January 4th of each year, when the earth is nearest the sun. The minimum size will be observed six months later, at the beginning of July, when the earth is at aphelion, about three million miles farther from the sun.

Let the measured drift times on these dates be T and t, respectively. Then the eccentricity of the earth's orbit is given very nearly by

$$e = (T - t)/(T + t).$$

It is not difficult to obtain a good approximation to the actual eccentricity (0.0167) in this way.

When an observatory is eventually established on the moon, one of its more important tasks may be to measure the earth's apparent magnitude and how its brightness changes. This problem is, however, not completely beyond the reach

The gibbous earth, as it might be seen from the moon, is depicted in this oil painting by Howard Russell Butler, which is an exhibit of the American Museum-Hayden Planetarium in New York City.

The south celestial pole is at the center of these trails of south circumpolar stars, a 1½-hour exposure by A. J. Symonds, Dunedin, New Zealand.

of the amateur who has stayed at home. When the moon appears a narrow crescent, its dark part is faintly illuminated by sunlight that has been reflected from the earth to the moon and thence back to the observer. Any drastic change in the earth's reflecting power should, therefore, cause a corresponding change in the intensity of lunar earthshine.

Many years ago, J. Plassmann in Germany proposed that systematic records be kept of the visibility of earthshine, this to be estimated on a numerical scale ranging from 0 for invisible to 10 for abnormally conspicuous. Amateurs who make regular evaluations of this sort will be rewarded by familiarity with a beautiful spectacle only casually known by most watchers of the sky.

The terrestrial atmosphere has several properties worth study by the home observer. One of these is the refraction of light. Rays entering the atmosphere are bent toward the earth, the amount of this refraction being greater the nearer an object is to the horizon. Reaching the eye, the refracted light thus makes the object seem higher in the sky than it actually is. At sunrise and sunset the sun appears flattened. Although all the light rays are refracted, those from the sun's lower edge are bent by a greater amount, raising the lower part more than the upper and causing the solar disk to appear elliptical.

Another effect worth exploring is the dimming of starlight as it passes through the air. This *extinction* amounts to one-fourth of a magnitude for a star at the zenith, and increases in amount, slowly at first and then more rapidly, toward the horizon, where the path of light through the air is many times longer.

If z is the angular distance of a star from the zenith, the extinction of its light, in magnitudes, amounts to approximately 0.25 secant z, so that at a zenith distance of 60 degrees the dimming is 0.50 magnitude, and at 75 degrees about 0.97. In other words, a star 15 degrees above the horizon appears only about half as bright as it would if placed overhead.

One way to judge the amount of extinction is to compare two stars of known brightness, one star near the horizon being viewed directly, while another nearly overhead is seen in a small mirror held at arm's length. The altitudes of the stars can be roughly measured with a protractor and plumb line. It may be convenient to attach this device to the tube of a small altazimuth telescope; after the star is placed in the field of view, the protractor is read.

The earth's atmosphere gives rise to a host of other striking optical phenomena easily studied by the amateur with unaided eye or simple equipment. For instance, the limits of visibility of stars and planets by twilight and by day form a subject worth attention. Halos, twilight phenomena, and the scintillation of stars are other examples. All these topics, and many others, are described in one of the most fascinating books written for the amateur scientist, M. Minnaert's *Light and Colour in the Open Air* (Dover Publications, 1954).

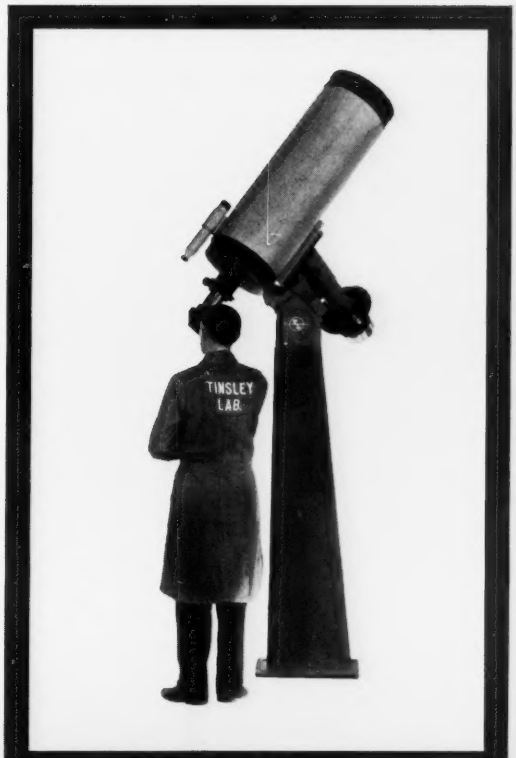
LETTERS

Sir:

Although we have no amateur society in our city, on June 2nd several of us who own telescopes sponsored the first public star party ever held in Fargo, North Dakota. The event was publicized through the undersigned's daily weather program on the local television station. The turnout was very gratifying, more than 300 persons attending. The picture below shows a small part of our setup.

We had about 17 telescopes, including two 6-inch and two 8-inch reflectors and a pair of 3-inch refractors. Mimeographed sheets, describing the celestial objects being observed through the instruments, were distributed to the viewers.

DEWEY BERGQUIST
Station WDAY-TV
Fargo, N. D.



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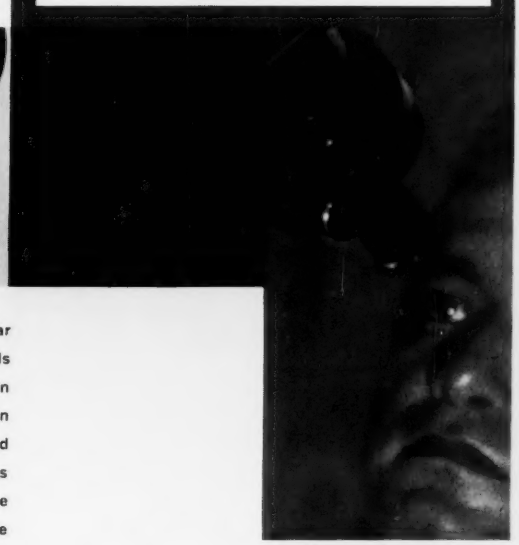

Here is a new instrument of traditional Tinsley quality at a cost far below that of a custom telescope. Ideal for astronomy clubs, schools and advanced amateurs. Specifications: 12-inch aperture. Casse grain optical system. Primary mirror focal length 48". Secondary amplification 4; total effective focal length 192". Eyepiece image lies 16" behind reflecting surface of primary mirror. Overall tube length 43", plus focusing assembly. Tube is easily removable from mounting. • Eyepiece focusing assembly: rack-and-pinion type, extremely rugged and adaptable for cameras and accessories. • Mounting: has positive clamps for declination and right ascension. Motor driven in right ascension to a precise sidereal rate. Additional motor control for fast rate is 5 times the sidereal rate. Manual declination with anti-backlash. Setting circles are large and precision engraved. • Provides for precise orientation of polar axis. • Optical surfaces: accurate to ⅛ wave length or better. Reflecting surfaces aluminized and have a protective overcoating. Refracting surfaces have low-reflection coating. • Equipped with a finder of 10 power. • Mounted on a steel pedestal. • For an illustrated folder, write to Tinsley Laboratories, Inc., Dept. S, 2526 Grove Street, Berkeley 4, California. □ Tinsley's new 16mm full-color, sound film "Eyes to the Sky"—the story of precision telescopes—is now available for loan showings. Please address requests to the Audio-Visual Department.

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OBSERVER'S PAGE

Universal time (UT) is used unless otherwise noted.

More About Comet 1959k

DURING late April and the first days of May, sky watchers enjoyed the spectacle of a naked-eye comet that moved rapidly across the northern sky, passing through Cygnus, Ursa Minor, and Ursa Major. This was Comet 1959k, discovered last December 30th by Robert Burnham, Jr., at Lowell Observatory. The early history of this object was reported in Sky and Telescope for March, page 292, and June, page 479.

Intrinsically a small comet, 1959k became slightly brighter than magnitude 5 because it passed close to the earth, the least distance being 19 million miles on April 29th. This proximity was brief, as the comet receded to 23 million miles by May 1st, 54 million on the 12th, and 100 million on May 26th. Meanwhile, the comet was moving away from the sun, being 136 million miles from it on the last-mentioned date, compared to its perihelion distance of 47 million miles on March 20th.

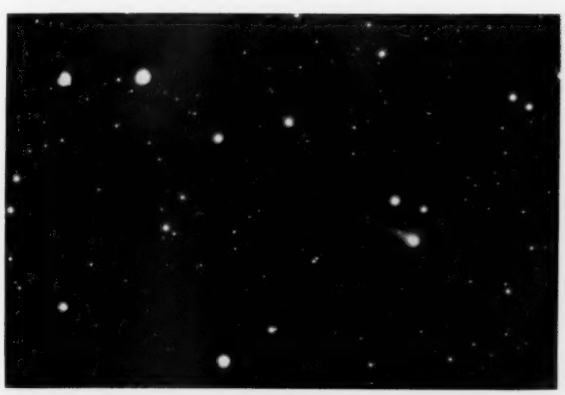
This 45-minute exposure of Comet Burnham is by John G. Kirk, at 2:26 UT, May 3, 1960, with the 4-inch f/7 Ross camera of Amherst College.

While it was in the earth's vicinity, many amateurs took the opportunity to make visual and photographic observations of this bright and favorably located object. Reports, most of them accompanied by photographs or charts, have been received from the following readers, in addition to those mentioned in previous articles: W. C. Atkinson, New York, New York; R. Ankersmit and J. Kamperman, Utrecht, Netherlands; K. Brandl, Munich, Germany; A. J. Doig, Dunedin, New Zealand; M. O. Guidry, Jr., Metairie, Louisiana; J. G. Kirk, Amherst, Massachusetts; Rev. J. Knowles, Jamaica, New York; N. Liepins, Sandwich, Illinois; E. G. H. Mobsby, Shillingstone, England; J. Wesley, Grand Rapids, Michigan; H. Willis, Lone Oak, Texas; and J. Wiseman, Portland, Oregon.

One peculiarity of Comet Burnham that impressed many observers was the faintness of the tail, much less conspicuous than for typical comets of similar brightness. It was best revealed by photography, the greatest recorded length being 11½ degrees, on long exposures by R. Waterfield, Ascot, England. But this narrow, straight appendage was so faint that Mr. Mobsby recorded it as quite invisible in his 8-inch reflector on April 28th, and on the following night Mr. Ankersmit was unable to see it in a telescope of the same aperture.

Increasing distance from the earth and sun caused a rapid fading of 1959k during May. This is well shown by the many visual estimates of magnitude, from out-of-focus comparisons with stars in binoculars or small telescopes. Elizabeth Roemer, at the U. S. Naval Observatory's Arizona station, found magnitude 4.6 to 4.7 on April 29th. She reported 5.4 for May 1st and 6.6 for May 6th. Some later observations by A. Wroblewski in Poland are: May 9, 8.5; 12, 9.2; 15, 10.0; and fainter than 12 on May 21st.

A careful distinction should be made between comet magnitudes determined visually with small instruments, and pho-



On April 9th, at the Beverly Begg Observatory in New Zealand, Arthur J. Doig took this 30-minute picture of Comet 1959k. He employed an f/6.3 Dallmeyer camera of 36-inch focal length, Ilford Zenith emulsion, beginning the exposure at 17:10 UT. At the upper left are Theta and Rho Aquarii, and south is at top. The scale is about two degrees per inch.

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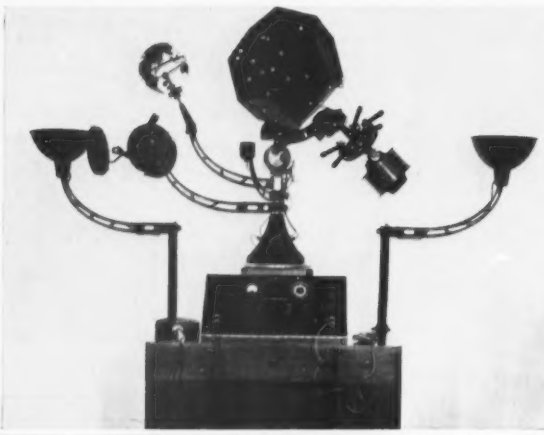
tographic magnitudes obtained with large telescopes. In the former case the total light of the coma is included. On the other hand, photographs taken for the purpose of measuring precise positions are given only enough exposure to bring out the nuclear region of the comet.

Thus on April 29th, when the visual magnitude of the head was about 5, Dr. Roemer's photograph with the Naval Observatory's 40-inch reflector gave 12.5 for the magnitude of the nucleus. Her plate of May 25th showed a sharp nuclear condensation of about magnitude 17.5, inside a coma 0.7 minute of arc in diameter, as well as a faint tail 12 minutes or more long.

By June, Comet Burnham had become extremely faint. Dr. Roemer's 60-minute exposure, reproduced here, shows little more than a nearly starlike condensation of the 18th magnitude. On July 13th, only the barest trace of the comet, too slight to be measured, was recorded on her one-hour 40-inch-reflector plate.

During the coming fall and winter, after 1959k has passed conjunction with the sun, it may possibly be photographed with very large telescopes for the last time as a 20th-magnitude object in Coma.

The faint, fuzzy spot below center is the comet on June 17th, taken by Elizabeth Roemer with the 40-inch reflector at the U. S. Naval Observatory's station in Flagstaff, Arizona. The print scale is 6.2 seconds of arc per millimeter, the negative showing a narrow comet tail 20 minutes of arc in length.



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SUNSPOT NUMBERS

The following American sunspot numbers for June have been derived by Dr. Sarah J. Hill, Whitin Observatory, Wellesley College, from AAVSO Solar Division observations.

June 1, 91; **2,** 80; **3,** 101; **4,** 72; **5,** 95; **6,** 106; **7,** 113; **8,** 110; **9,** 126; **10,** 129; **11,** 129; **12,** 112; **13,** 112; **14,** 120; **15,** 171; **16,** 119; **17,** 98; **18,** 94; **19,** 78; **20,** 51; **21,** 48; **22,** 42; **23,** 62; **24,** 74; **25,** 82; **26,** 92; **27,** 95; **28,** 119; **29,** 128; **30,** 128. Mean for June, 99.2.

Below are provisional mean relative sunspot numbers for July by Dr. M. Waldmeier, director of Zurich Observatory, from observations there and at its stations at Locarno and Arosa.

July 1, 167; **2,** 154; **3,** 161; **4,** 203; **5,** 168; **6,** 139; **7,** 119; **8,** 124; **9,** 120; **10,** 97; **11,** 93; **12,** 74; **13,** 83; **14,** 93; **15,** 105; **16,** 138; **17,** 131; **18,** 122; **19,** 143; **20,** 137; **21,** 139; **22,** 135; **23,** 127; **24,** 105; **25,** 111; **26,** 92; **27,** 90; **28,** 73; **29,** 94; **30,** 82; **31,** 83. Mean for July, 119.4.

QUESTAR NEWS • *September, 1960*

Here are two Questar photographs of Jupiter, made on different nights last July by Mr. and Mrs. Ralph Davis, who have taken so many fine pictures with their Questar. Mrs. Davis sent along the negative from which the lower one was enlarged, and the image measured .041 inch wide, exactly half the diameter of the head of a common pin. This print is a 29x enlargement.

The film used is the new and faster Microfile, which is now called Kodak High Contrast Copy Film (35 mm.). "This film has a high-contrast, special panchromatic emulsion, with extremely low graininess and extremely high resolving power. It is especially designed for making greatly reduced copies of books, newspapers, manuscripts, line drawings, letters, etc. It should be used whenever the copy negatives represent more than a tenfold reduction in size," says the factory enclosure sheet. Its tungsten speed is 64, four times faster than it used to be.

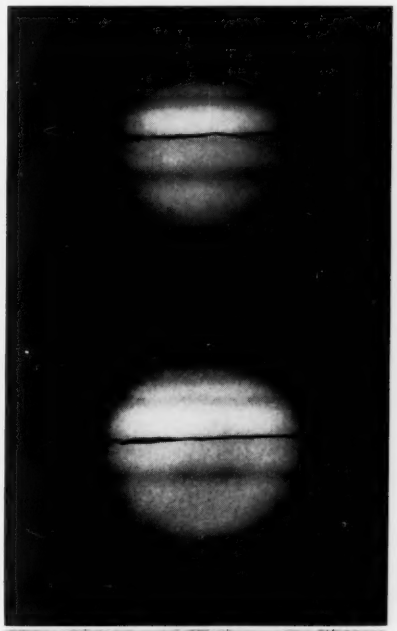
The Davises use fine-grain films to get all resolution possible. Incidentally, these Jupiter shots were two-second exposures at f/56, so the little Questar was performing with an actual focal length of 16 feet, obtained by eyepiece projection with our basic coupling set, which focuses the enlarged image on a film placed a few inches behind the eye lens. By varying the distance, the image size can be changed, which changes exposure requirements. Experiment alone will determine the best exposure time-size ratio to use for various objects.

When visiting the Davises in the spring of '59, we were astonished to see how much more detail one can see on a negative than can be printed from it. In discussion, either Dot or Bud Davis is apt to whip a Questar 40x eyepiece to the eye, holding it backward and looking through the field lens, to examine a negative held closely to the eye lens of the ocular against the light. (Both say that it becomes just the right magnifier for this work, and so it does when you try it.)

Now we begin to understand why the professional becomes a negative searcher. He simply knows there is more to be seen on emulsions than any print can show. The Davises were showing us negatives of sunspot groups.

They had been exposing and printing for the tiny solar granulations they have so beautifully resolved from their own yard at sea level with the miniscule Questar. Nearly every large sunspot of a group like this shows a network of bridges, streamers, and traceries crossing it. There they are on the negatives — but try to print them on paper! They fade out in development as heavier parts of the image seem to overpower them. Well, the Davises say they intend to keep trying.

Of late we have had some inquiries asking what the faintest star magnitude is for Questar. The answer is that Questar will show stars as faint as can be expected of all telescopes of 3.5-inch aperture. But we hesitate to put a number on it. We keep meeting those who live in cities like Philadelphia who say they never see the Milky Way because the sky is luminous at night from the overcast of smog. So we tell them to expect Questar to show the standard limiting magnitude for this aperture, but please to remember that only in fine climates with transparent skies can Questar do its best in this respect. And we remind them that while smog may spoil faint objects it sometimes acts to stabilize the seeing for planetary detail and the separation of close doubles.



Finest seeing we have ever had was on a night near Pittsburgh before the region controlled its industrial fumes, when the air was so thick with smoke the moon was reduced to a yellow color when high in the sky.

Recently we mailed to all Questar owners of record a little leaflet on taking pictures through high-power telescopes like Questar. We tried to set down on paper what we had learned about this business of using the tremendously popular 35-mm. cameras to take pictures employing the versatile Questar as a series of lenses with focal lengths of from four to over 50 feet. We speak of some rules for this kind of photography, in order to give the newcomer to this fascinating field a clear concept of what must be done, rather than the exposure tables most novices request. We balk at these because there are too many variables, and anything we put on paper for our climate might prove vastly untrue in theirs. If you would like a copy, just drop us a postcard and we will gladly send you one.

No sooner were our 2,000 little leaflets printed than we noticed with dismay that we had forgotten to say one single word about the cameras we carry here to sell along with Questars. As we write, it is mid-July, and we have just purchased from the world's largest photographic house 50 more Pentacon cameras they located for us with f/2.8 lenses. We are mighty pleased to have these, because they are the very cameras sold beneath the pasted-on nameplate "Hexacon." No use trying to understand today's mad and senseless camera market — we shall try to acquire, whenever we are able, some proven cameras at loss-leader prices to be sure you will be protected from the worst of the price cutting. In the case of the new Pentacons, this is the original Zeiss Contax D or S model, that first sold at some $400. It has the many speeds and the self-timer that can release the mirror soon enough to avoid fully its recoil effect during exposure. This lot is spick and span, and some have Carl Zeiss lenses with the name carefully ground off for reasons still beyond our ken. We shall sell them with 10-inch cable release and our standard set of basic couplings for only $134.50 as long as they last. We are reasonably sure that after purchasing one you will not find them anywhere on sale at a lesser price.

We almost took on another inexpensive line only to discover that in the few weeks during which we were trying out the cameras their prices kept going down until they were selling at retail in one store for slightly less than dealer's net wholesale price!

So we have become duly franchised dealers for the Nikon line of photographic equipment, because it seems to be, in our considered opinion, the best obtainable. Their great single-lens reflex model F is, by test, they tell us, the camera whose focal plane shutter has least recoil because it is made of light titanium metal foil and is mounted in ball bearings. This shutter can be operated entirely alone with locked-up mirror when desired, and sure enough, we find it has the least recoil of any so far tested.

Every Nikon product is so beautifully made that you sense its quality at first glance. These are awfully nice people to do business with. They, too, worry about protecting your investment. To make sure their product is not artificially devalued by the discouraging price cutting which afflicts the camera market, their sales manager, Mr. J. Abbott, canceled the franchises of 28 price-cutting dealers in the month of May.

We think that protecting the customer's interest is very important in the building of a business. And we always liked the answer Nikon's president gave to the "Times" reporter who asked the secret of his company's superlative quality: "It is really very simple. You just throw away every piece of glass that is not exactly according to specifications."

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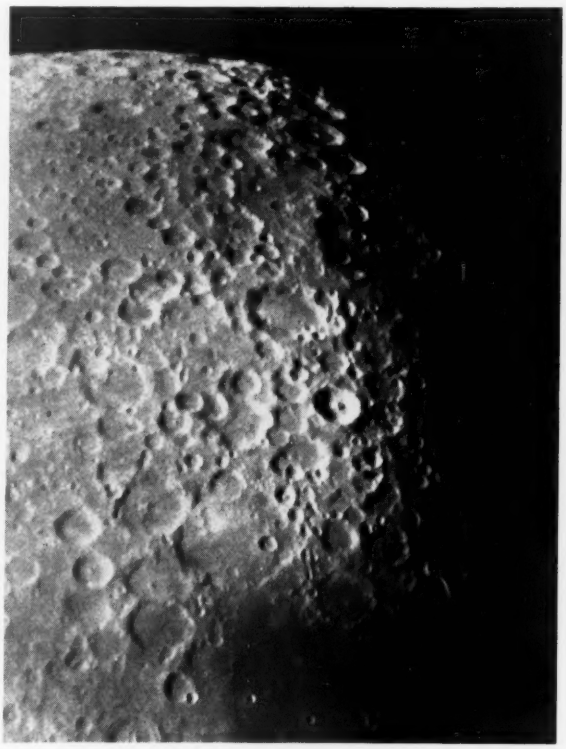
LUNAR PHOTOGRAPHY WITH A 6-INCH REFLECTOR

GOOD PHOTOGRAPHS of the moon can be taken with moderate-size telescopes, even if they are not equipped with drives or slow motions. The moon is so bright that with modern fast films the exposure need not be more than 1/10 second. Thus the telescope can remain stationary during the exposure, without serious trailing. The accompanying pictures were made in this way with my homemade 6-inch f/12 reflector.

For prime-focus photography, an adapter on the eyepiece tube takes holders for 2¼-by-3¼-inch sheet film. A 35-mm. camera of the single-lens reflex type could be used the same way, with the advantages of the thin-emulsion fine-grain 35-mm. films available today. For focusing, I use a piece of ground glass fitted into the adapter in the same plane as the film.

Instead of a mechanical shutter, I employ a large piece of sturdy cardboard, in which a hole the size of the mirror has been cut. Painted black, this cardboard is large enough to cover easily the open end of the telescope tube. When less light is needed, the size of the hole is reduced by a mask. Only a 1½-inch hole is needed for a full-moon exposure on Panatomic-X film with my telescope.

To make an exposure, a filmholder is inserted in the adapter, and the tube end is covered by the cardboard before the slide is removed. After waiting a few seconds for vibrations to stop, the shutter is quickly moved downward to uncover the tube momentarily for the exposure. The speed of the exposure is about 1/10 second, sufficient for a good image, and with a little practice consistent results are obtained by this method.



The southern part of the moon, photographed by Robert T. Dobson with his 6-inch reflector and a Barlow lens on December 30, 1957, at 6:23 p.m. Eastern standard time. The 1/10-second exposure was on Verichrome Pan film. To the right of center, the prominent crater with a central peak is Tycho. An inch above it is Clavius, 144 miles in diameter. More than an inch below Tycho is Pitatus, with its wall broken down on the side bordering Mare Nubium. Near bottom center is a fine vertical dark line, which is the shadow that the Straight Wall casts to the east.

At the primary focus of my telescope, the diameter of the lunar image is about 17½ millimeters. When an enlarged image is desired, I use a Barlow lens to triple the effective focal length. Because of the enlargement, some light is lost, and a faster film is needed. Although I have had some good results by force-developing a slow film, this is not recommended as a standard practice.

For lunar photography, film should have moderate contrast, good latitude, and fine grain. Many such emulsions are now available, but most often I use Panatomic-X sheet film. For the full moon, a contrast film shows the ray systems well. When pictures are taken

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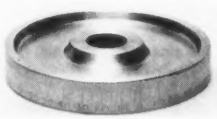

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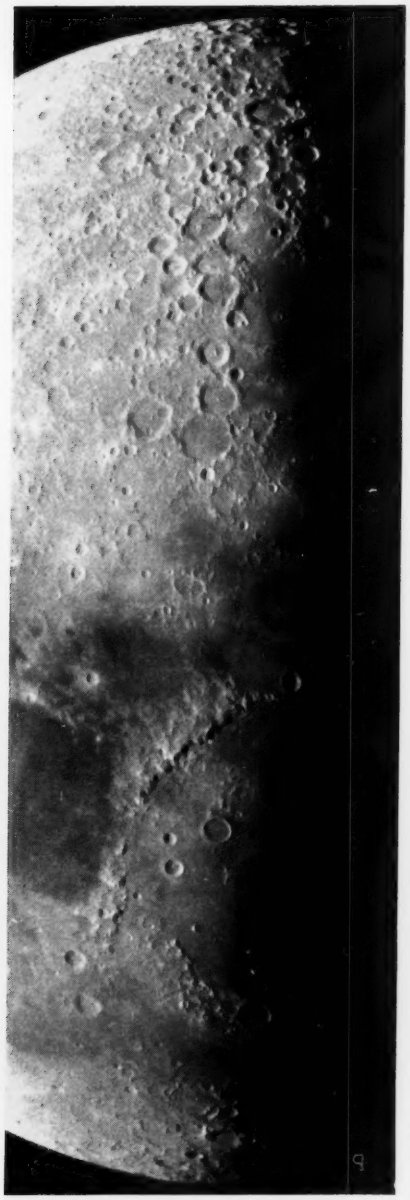

The first-quarter moon, taken at the prime focus of the 6-inch reflector on March 28, 1958, at 7:58 p.m. EST. The 1/10-second exposure on Panatomic-X roll film was developed in Rodinal for 11 minutes. The prominent mountain range a little below center is the lunar Apennines. South is to the top.

through the Barlow lens, Verichrome Pan in film packs or Super Panchro-Press B sheet film are employed.

Among the developers tried are Agfa Rodinal, Ilford Microphen, Clayton P-60, and Kodak DK-50. The first three are fine-grain developers. Rodinal is particularly good for thin-emulsion films, and generally useful. The highly concentrated solution can be diluted with water to suit the characteristics of the film.

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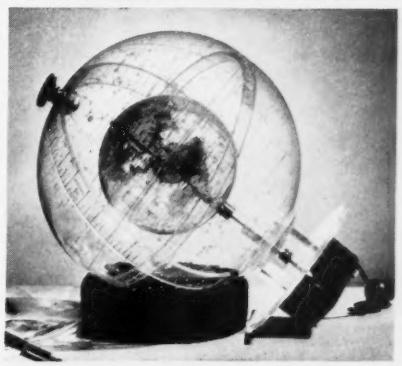

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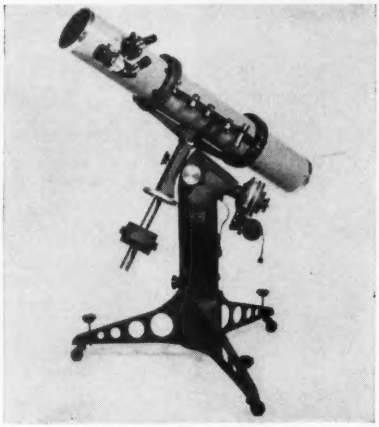

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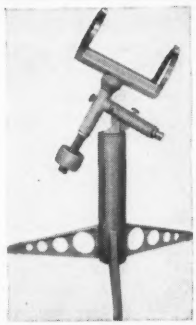

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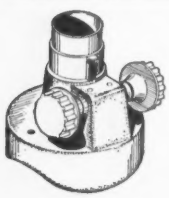

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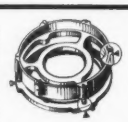

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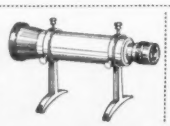

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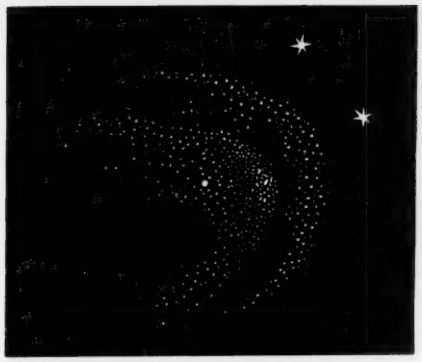


Admiral W. H. Smyth made this drawing of Messier 11 in 1835, with the 5.9-inch refractor of his private observatory at Bedford, England. He published it as a woodcut in his "Celestial Cycle" (1844). His rudely schematic depiction is more a historical curiosity than a scientifically accurate chart.

DEEP-SKY WONDERS

EXCEPT for such fine examples as the Pleiades and Praesepe, galactic star clusters tended to be belittled in the older observing manuals for amateurs. Often described as "poor," "thin," and "sparse," they seemed to be a minor phenomenon compared to the spectacular, densely packed globular clusters.

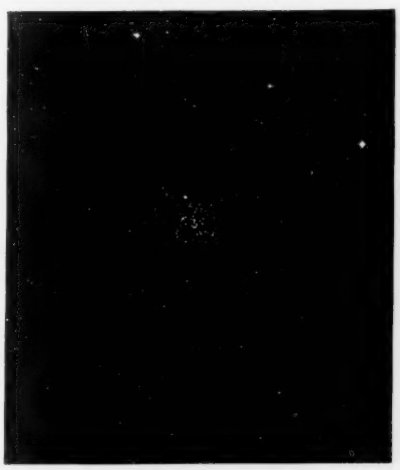
Today, the pendulum is swinging the other way. More and more amateurs are finding these well-resolved star groups rewarding objects in which rich detail is visible.

Messier 11 (NGC 6705) is in the constellation Scutum, at $18^h\ 48^m.4$, $-6°\ 20'$ (1950), and is labeled on the star chart on page 177 of this issue. Within six minutes of arc from its center, there are about 600 stars brighter than magnitude 15. The cluster stands out conspicuously against the background of the Scutum starcloud, as the photograph on page 142 shows.

With the unaided eye, M11 is visible on a clear, dark night as a faint blur. Binoculars give an interesting view, while a 2-inch telescope brings out some individual stars. However, a large instrument is needed to reveal its full splendor. My most spectacular view was with the 36-inch reflector of Steward Observatory in Arizona, when the whole field shimmered with stars. The 10-inch reflector I use in Kansas does very well on M11, and preserves the triangular shape of the cluster, lost in photographs, which prompted Admiral Smyth's description: "a flight of wild ducks."

Not far south of M11 lies Messier 26 (NGC 6694), at right ascension $18^h\ 42^m.5$, $-9°\ 27'$, about one degree east of 5th-magnitude Delta Scuti. While both clusters have about the same angular diameter, M26 has far fewer stars, only about 100 down to magnitude 15. The total light is about a match for an 8th-magnitude star. In my 10-inch, M26 makes a bright splash on the dark sky behind. Some visual observers see the outline as far from circular; one amateur has written me that the cluster looks roughly square, and indeed the accompanying Palomar photograph gives this impression. It would be interesting to compare its outline as seen in instruments of widely differing size.

WALTER SCOTT HOUSTON
Rte. 3, Manhattan, Kan.



This photograph of Messier 26 was taken with the 48-inch Schmidt telescope at Palomar Observatory. South is to the top, and the width of this field is 40 minutes of arc. M26 is nearly 7,000 light-years distant.

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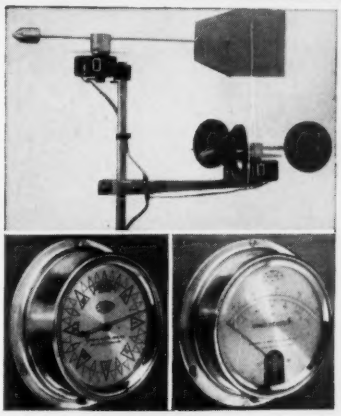

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During early mornings in September, a 10th- or 11th-magnitude comet can be observed in eastern Taurus. This is Comet Finlay, discovered in 1886, which comes to perihelion at intervals of just under seven years. Seen at every return except one until 1926, it was missed in 1933, 1940, and 1947, then rediscovered in 1953.

This year, Comet Finlay was first photographed at Lowell Observatory by R. Burnham on June 21st, and on the following night by Elizabeth Roemer at the U. S. Naval Observatory's station in Arizona. The comet is closest to the sun (100 million miles) on September 1st.

The British computer M. P. Candy has furnished an extended ephemeris in *Circular* 1734 of the International Astronomical Union, from which are extracted the following predicted right ascensions and declinations (1950 co-ordinates) for 10-day intervals:

August 24, $4^h\ 11^m.3$, $+14°\ 19'$. September 3, $4^h\ 57^m.5$, $+17°\ 40'$; 13, $5^h\ 36^m.6$, $+20°\ 00'$; 23, $6^h\ 08^m.9$, $+21°\ 36'$. October 3, $6^h\ 34^m.4$, $+22°\ 44'$; 13, $6^h\ 53^m.6$, $+23°\ 39'$; 23, $7^h\ 06^m.1$, $+24°\ 31'$.

According to Mr. Candy, the comet will be fading from magnitude 10.4 on September 3rd to 11.6 on October 13th. Because of the uncertainties in forecasting comet brightnesses, observers should be prepared to find the object somewhat brighter or fainter than predicted.

OBSERVATIONS OF SZ HERCULIS

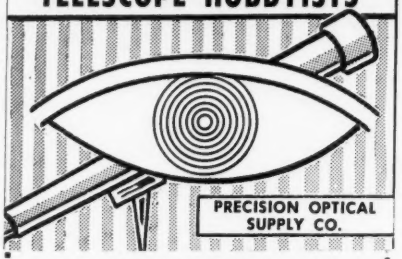
On page 508 of the June issue, a finder chart was given for the Algol-type variable star SZ Herculis. The 19.6-hour period is slowly changing, hence new determinations of the times of minimum light are desirable.

At Ciudad Juarez, Mexico, Hector Ayala R. made visual estimates of the brightness of SZ Herculis with a 6-inch reflector. During the minima of June 13-14, July 1-2, and July 10-11, he obtained 18, 15, and 12 observations, respectively. The minimum of June 27-28 was observed by J. Ashbrook at Weston, Massachusetts, with a 10-inch reflector. From this material, the following Julian dates of minimum light, corrected for light time, have been deduced:

J. D.	*O−C*	*Observer*
2,437,099.705	$+0^d.005$	HAR
2,437,113.614	+0.006	JA
2,437,117.699	+0.001	HAR
2,437,126.699	+0.002	HAR

The O−C's are the differences between the observed times of minimum and those calculated from the prediction formula in the 1960 *International Supplement* of the Krakow Observatory. It appears that during this summer the minima of SZ Herculis were coming 0.0035 day or five minutes later than predicted, on the average.

TELESCOPE HOBBYISTS



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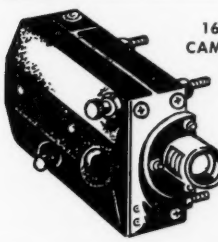

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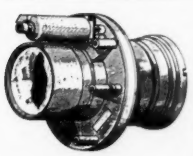

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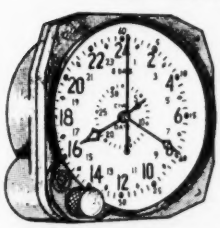

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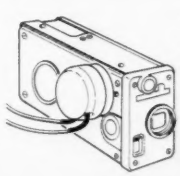

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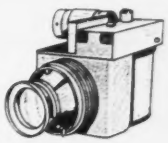

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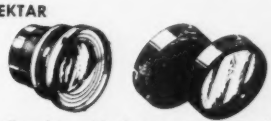

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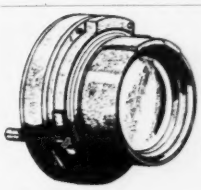

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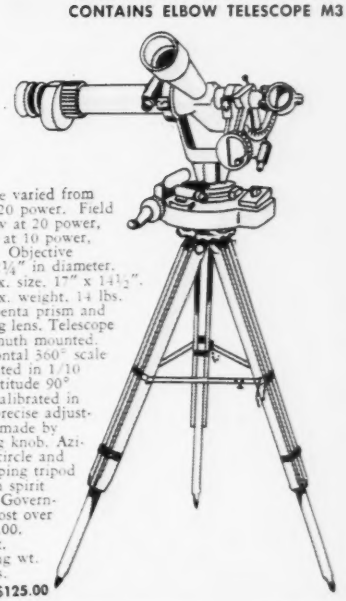

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BOOKS AND THE SKY

STANDARD HANDBOOK FOR TELESCOPE MAKING

N. E. Howard. Thomas Y. Crowell Co., New York, 1959. 326 pages. $5.95.

WITH the advent of the first artificial satellite nearly three years ago, interest in things astronomical has greatly increased, and a growing number of people want a good telescope to satisfy their enthusiasm. This book gives complete and detailed instructions for making such an instrument.

Of its 326 pages, some 230 are devoted to the actual construction of an 8-inch f/7 Newtonian reflecting telescope, while the remaining pages include discussions on building an observatory, astrophotography, and different types of telescopes. There are a glossary and 22 appendices supplying varied information.

Written for the novice, the book is well arranged, but while the directions are well presented and complete, they are unnecessarily long and wordy. Most of the material is not new; much may be found in the *Amateur Telescope Making* series and in Allyn J. Thompson's and Jean Texereau's manuals. However, some new techniques, particularly in polishing, are offered that may substantially reduce the time and labor usually required to complete the mirror.

The author elected an 8-inch telescope because it "is only a little more difficult" to build than a 6-inch. He does not stress some of the added problems of a larger instrument, particularly the need for more storage space, and the telescope's added bulkiness when moved about for an observing session. Unless the builder can supply satisfactory housing for his instrument, he may soon tire of it, relegating it to the attic, cellar, or garage.

The book's title is somewhat misleading, especially to persons familiar with the *Standard Handbook for Electrical Engineers, Handbook of Chemistry and Physics,* and similar volumes that give detailed data on all phases of their subjects. Here one expects information on making all types of telescopes and attachments, rather than just a simple reflector.

Very little is said about optical theory, and aberrations are discussed only in connection with eyepieces. The descriptions of telescope types, other than the Newtonian reflector, are very disappointing. While brief mention is made of Cassegrainian, Gregorian, Schmidt, and Maksutov instruments, no technical discussion is given. Even the refractor is passed over quickly, and somewhat unfavorably at that. There are no words on the Herschelian or the Schmidt-Cassegrainian types, or the Johnsonian modification of the Gregorian telescope.

The first five chapters deal with telescopes in general, the procedures for rough and fine grinding the mirror, types of strokes to use, data on abrasives and their grain sizes, and the principle of the Foucault test. Several varieties of testers are described, the Mackintosh type being very good and easy to construct.

Chapter 6 is on pitch laps and polishing. The messy job of making and channeling the lap is outlined, but there is no mention of using a V-shaped cutter attached to a hot soldering iron for cutting the channels. Several quick-polishing methods are given that may materially reduce working time. For the first hour of polishing, one method utilizes the finest of the fine-grinding abrasives on a pitch lap. It is then painted with hot beeswax to seal off the abrasive, and the polishing is continued with rouge. Another promising method is to cover a channeled pitch lap with a "fine-grained plastic material," applying the polishing agent (rouge, cerium oxide, or Barnesite) to the plastic surface. The usual periods of cold pressing are, of course, required.

The next section is concerned with testing the mirror, including the eyepiece and Ronchi tests for turned edge, and with correcting defects in the mirror's surface. The author gives ways to take care of raised and depressed zones, "dog-

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biscuit" surfaces, central bumps and depressions.

Chapters 8 and 9 deal with testing for the paraboloid and parabolizing the mirror. The mathematics of the mirror curve are discussed at length, and changes in the knife-edge settings are calculated. The permissible tolerance is given as 25 per cent for the 8-inch f/7 mirror. This calculation is based on the Rayleigh limit, following the line of reasoning set forth by F. B. Wright in his article in *Amateur Telescope Making — 1* (page 257). It would have been helpful if the author had included Wright's table on tolerances for mirrors from four to 36 inches in diameter and for focal ratios of f/4 to f/12. Such information is of considerable interest today.

The figuring methods include parabolizing by long strokes, by using a subdiameter lap, and by a deformed or reversed lap. No choice as to the best way is expressed by the author. For final judgment as to the accuracy of parabolization, knife-edge readings are taken at four zones, with the results plotted on graph paper in the manner described by Wright. Also plotted are the 25-per-cent undercorrected, the 100-per-cent corrected, and the 25-per-cent overcorrected curves. Deviation of the actual mirror curve will show the degree of correction in terms of wave length, if the 25-per-cent under and over limits may be taken as $\frac{1}{4}$-wave correction.

The next two chapters are devoted to making diagonal mirrors and eyepieces. Ways to cut, grind, and polish the glass for the diagonal are given. The common types of oculars are described, and methods for calculating the equivalent focal lengths of various lens combinations. Spherical and chromatic aberrations in eyepieces are mentioned, as well as other optical defects. We are told how to put together eyepieces with lens elements from old cameras, field glasses, and other available equipment.

Then come three sections on the telescope tube and attachments, the equatorial mounting, setting up the instrument and adjusting it. Mr. Howard believes that fiberglass makes the best tube, and he gives rather detailed instructions on fashioning tubes and other parts from this material. This is a welcome addition to telescope making literature. A minimum of machine work is needed for the several mountings proposed. Instructions are given for putting together the mirror cells, spider, diagonal holder, several types of eyepiece holders, setting circles, as well as the gearing for simple clock drives.

In Chapter 15, on observatories and their construction, there are examples of sliding-roof and dome installations. Principal features are covered in a general manner, but the details are left for the builder. It would have been helpful if drawings showing the sections through the walls of both observatory types had been included.

In the celestial photography section (Chapter 16), there are many hints, including formulas for calculating width of field, image size, and effective focal ratio when eyepiece projection and camera lenses are employed. Exposure times, types of film, developing procedures, and guiding problems are discussed from a practical standpoint.

Numerous photographs and well-executed diagrams and drawings are used throughout the book. More photographs of amateur-made equipment, as well as of commercial telescopes, would help round out the presentation.

HOY J. WALLS
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Harlan J. Smith. Films for Education, New Haven, Conn., 1960. Six filmstrips, $42.00.

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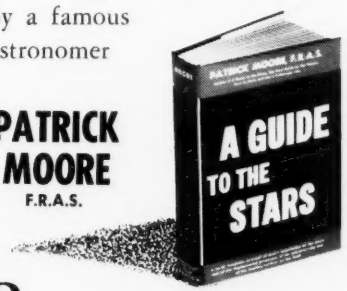

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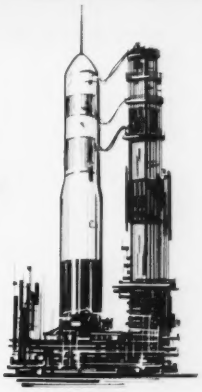

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4. "The Giant Planets" (76 frames) first presents Jupiter as typical of the giant planets and then proceeds to the others. A very timely discussion of radio emissions from Jupiter is followed by a detailed argument from density considerations that this planet is composed of light elements. Most of the treatment of Saturn is given to the ring system. Uranus, Neptune, Pluto, and peculiarities of Pluto's orbit are the subjects of the final frames.

5. "Between the Planets" (59 frames) is a well-organized account of interplanetary matter. Asteroids are described as being ground out by nature's "celestial gravel mill." Treatment of comets is most complete, as is that of meteors and their relation to comets, and meteorites. Finally, kinds of meteors, and the possible effect of meteors and solar plasma clouds on space travel are presented.

6. "Our Sun" (44 frames) begins by asking the classical questions about the sun — how hot is it, what is it made of, why does it shine — and then answering them one by one. Corona, chromosphere, prominences, photosphere, and hydrogen fusion are described in some detail. We

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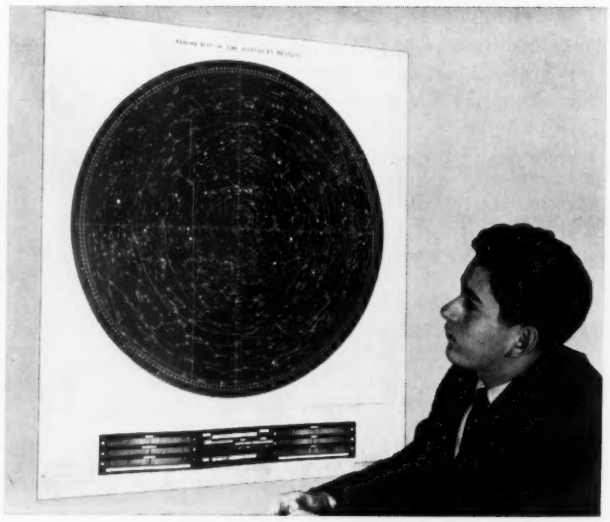

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HANDBOOK OF GEOPHYSICS, *U. S. Air Force,* 1960, *Macmillan.* 656 pages. $15.00.

First published in 1957 for the exclusive use of U. S. Air Force prime contractors, this book has now been revised and brought up to date for general distribution. Consisting mostly of technical data, it was prepared by 60 civilian scientists employed by the Air Force, and covers all topics in meteorology and geophysics, including chapters on meteors, the sun, and cosmic radiation.

TRANSACTIONS OF THE INTERNATIONAL ASTRONOMICAL UNION, Vol. X, *D. H. Sadler,* editor, 1960, *Cambridge University Press.* 773 pages. $17.50.

The latest volume of the *Transactions* follows almost exactly the model of the previous one, containing the main proceedings, draft reports of the individual commissions, and the four joint discussions of the 10th general assembly of the IAU, held at Moscow in 1958. The symposiums that took place in conjunction with the meeting are to be published separately.

Also included in this volume are the minutes of the general sessions, texts of all the resolutions adopted, and the statutes and membership list of the union. The text is largely in English, with some sections in French.

MOON MAPS, *H. P. Wilkins,* 1959, *Macmillan.* 65 pages. $6.00, spiral bound.

The 25 principal charts depict the lunar surface as seen under conditions of mean libration, and a special one shows detail in the great walled plain of Ptolemy. These maps were previously published in *The Moon* by Wilkins and Patrick Moore, which contained libration charts omitted in this reissue. The map scale is roughly 40 inches to the moon's diameter. There is a 28-page alphabetized list of named lunar objects.

THE EXPLORATION OF THE SOLAR SYSTEM, *Felix Godwin,* 1960, *Plenum Press.* 200 pages. $6.50.

The 19-year-old author deals with the problems of interplanetary travel, including his designs for the space vehicles to be used. He is concerned mainly with exploring the moon, Venus, and Mars.

THE EXPLORATION OF SPACE, *Robert Jastrow,* editor, 1960, *Macmillan.* 160 pages. $5.50.

Thirteen papers and three round-table discussions on astronomy, astrophysics, and space research, given at a symposium in April, 1959, are here gathered in book form. Included are articles on the moon by G. P. Kuiper, meteorites by H. C. Urey, and the planets Mars and Venus by G. de Vaucouleurs.

NINE PLANETS, *Alan E. Nourse,* 1960, *Harper and Bros.* 295 pages. $5.95.

The solar system is discussed for the general reader, with imaginative illustrations of the planets by Mel Hunter.

COSMIC RADIO WAVES, *I. S. Shklovsky,* 1960, *Harvard University Press.* 444 pages. $12.50.

A comprehensive description of the nature and sources of radio emission from objects located far beyond the solar system is presented in this Russian monograph, now in English translation. Current major problems in radio astronomy, dealing with emission nebulae, interstellar gas in the galactic nucleus, and supernovae, are investigated.

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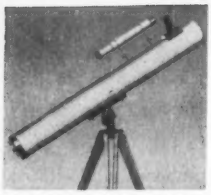

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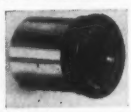

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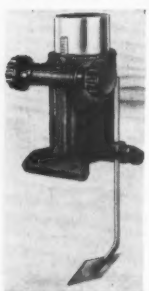

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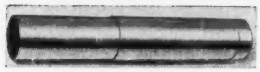

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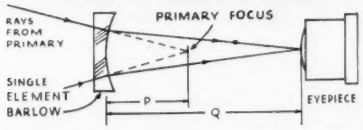

WHAT IS A BARLOW? A Barlow lens is a negative lens used to increase the power of a telescope without resorting to short focal length eyepieces, and without the need for long, cumbersome telescope tubes. Referring to the diagram above, a Barlow is placed the distance P inside the primary focus of the mirror or objective. The Barlow diverges the beam to a distance Q. This focus is observed with the eyepiece in the usual manner. Thus, a Barlow may be mounted in the same tube that holds the eyepiece, making it very easy to achieve the extra power. The new power of the telescope is not, as you might suppose, due to the extra focal length given the objective by the difference between P and Q. It is defined as the original power of the telescope times the quotient of P divided into Q.

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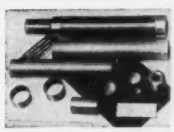

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Spider Diffraction in Moderate-Size Telescopes

WHAT type of support should be used to suspend a diagonal or secondary mirror in the tube of a reflecting telescope? We find three- or four-legged struts, single vanes, circular spiders, and the like, each type with its ardent advocates.

There is now available an excellent analysis of diffraction effects in telescopes, written by Edgar Everhart, University of Connecticut physics department, and Joseph W. Kantorski of American Optical Co.'s research division. Their paper, "Diffraction Effects Produced by Obstructions in Reflecting Telescopes of Modest Size," appeared in the December, 1959, issue of the *Astronomical Journal*.

It is well known that the image of a star, even in a perfectly made telescope, is not a point but a small circular disk of light. The size of this disk determines how well the telescope can resolve detail, and depends on the instrument's aperture. In the ideal case, where there are no obstructions in the optical path (as in a refractor or off-axis reflector), this central spot will contain 84 per cent of the light energy from a star, the remaining 16 per cent being spread into a system of concentric rings.

The disk and rings together are called the diffraction pattern, and the ideal case is illustrated in Fig. 1. The other parts of Fig. 1 show how the diffraction pattern is modified as successively larger central circular obstructions (such as a secondary mirror) are placed in the light path. The first ring becomes stronger and the second weaker as the obstruction ratio increases.

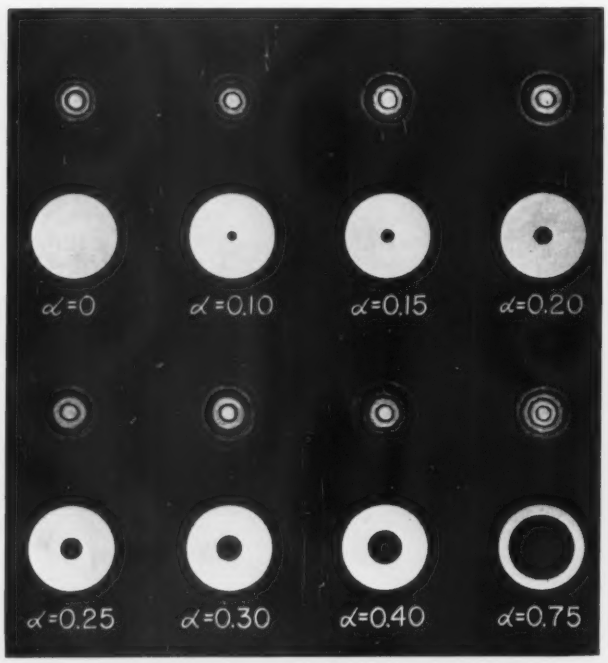
However, the most important effect of enlarging the obstruction is that less energy goes into the central disk and more into the rings. The result is a decrease in contrast, which will be discussed quantitatively later.

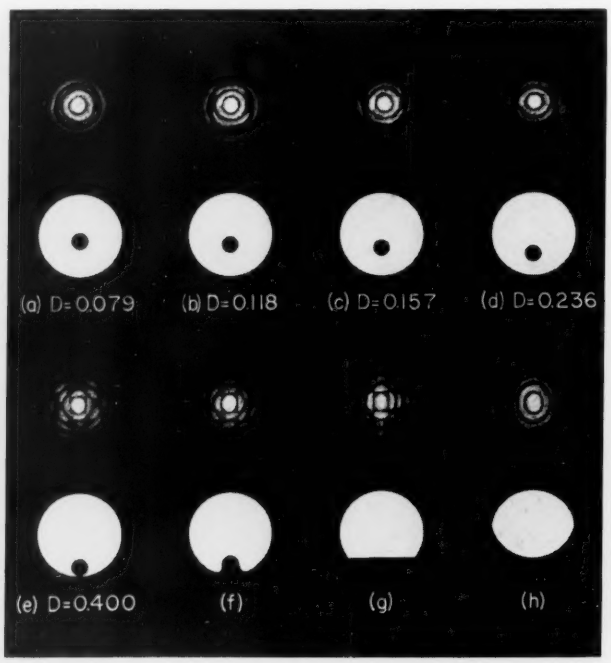
Fig. 2 shows the diffraction pattern obtained when the central obstruction is square, as with a secondary prism, and Fig. 3 depicts the result of decentering a circular obstruction. These patterns were obtained experimentally, since they would be very difficult to compute.

In a telescope the supports for the secondary mirror cause many interesting modifications of the diffraction pattern. The authors had the following comments.

a. Four supporting arms. Telescope makers know that the struts carrying the secondary cause spikes and other changes in the ideal pattern. Comparative photographs and drawings were made of the patterns produced by four struts holding a central stop of one-fifth the aperture's diameter.

The supports were made from wire of various diameters and arranged as shown in Fig. 4a. The width, W, of the strut is expressed as a fraction of the aperture. Fig. 4b shows the diffraction pattern for a rather severe case, $W = 0.070$; spikes are prominent, and the first ring has taken on a diamond shape. This value of W, corresponding to arms 0.7″ wide in a 10-inch telescope, is much larger than would be found in a practical design. As W is reduced to 0.032, the spikes become longer





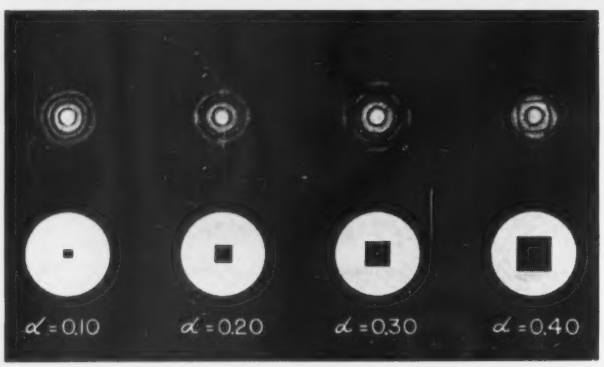


Fig. 1 (upper left). The diffraction pattern formed by an artificial star is shown as modified by circular obscuring disks placed in the light beam. α is the ratio of each disk's diameter to the aperture of the image-forming mirror.

Fig. 2 (left). The circular obscuring disk is replaced by a square one. As in Fig. 1, the inner diffraction ring is strengthened as the size of the obscuration is increased. However, in this case the outer rings are broken into segments, more noticeable for the larger obstructions.

Fig. 3 (above). A circular disk suspended off center on fine glass fibers gives these effects. D is the ratio of the off-center distance to the aperture's diameter. All illustrations with this article are from Edgar Everhart and Joseph W. Kantorski, courtesy "Astronomical Journal."

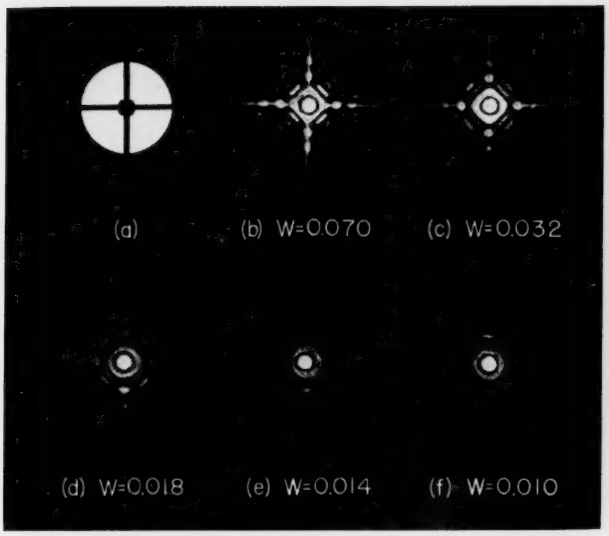


Fig. 4. Successively thinner supporting struts yield these diffraction patterns. The strut widths, labeled W, are given as fractions of the aperture of the image-forming mirror.

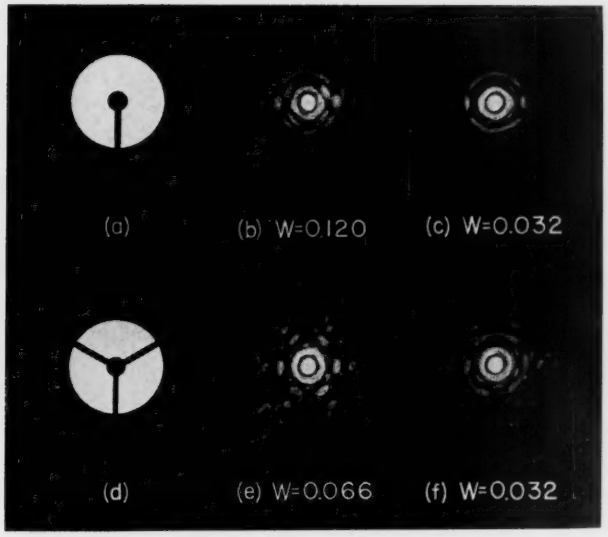


Fig. 5. Compare the diffraction patterns formed by a single-strut (above) and by a three-strut spider (below). The latter spreads much light into six broken rays.

and less intense. For $W = 0.018$ the spikes were too faint to record photographically, but when the camera was replaced with an eyepiece, they could be easily seen.

b. Single supporting strut. A series of photographs was taken of the patterns produced by the same central stop used above, but supported by a single arm (5a). The resulting patterns (5b and 5c) are comparatively simple. The two spikes are opposite one another, and are broader and fainter than in the corresponding four-vane patterns.

c. Three struts spaced symmetrically. With the same stop supported by three legs 120° apart (5d) the patterns had six spikes as expected (5e and 5f). These have an unusual soft-textured structure, caused by overlapping of maxima and minima within each spike.

d. Unusual forms of struts. Many kinds of special supports have been suggested that modify or tend to eliminate the diffraction spikes.

Fig. 6a shows the pattern for two arms 90° apart. It resembles the four-arm ones in Fig. 4. Fig. 6b depicts two parallel sup-

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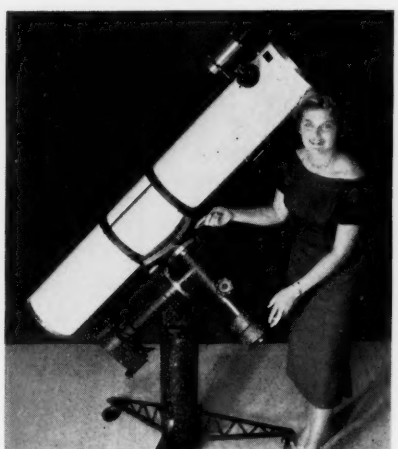

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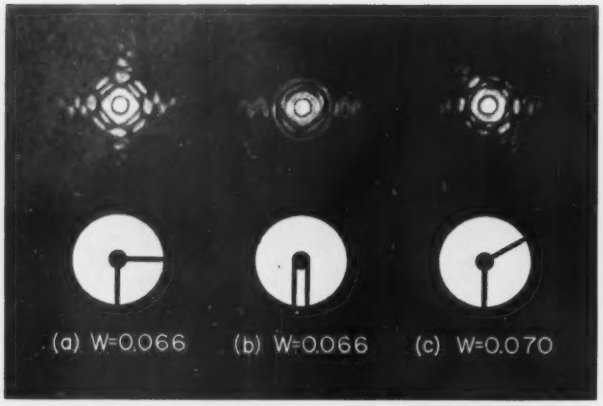

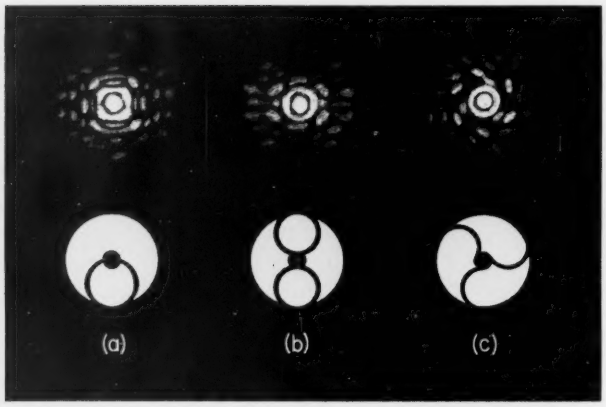

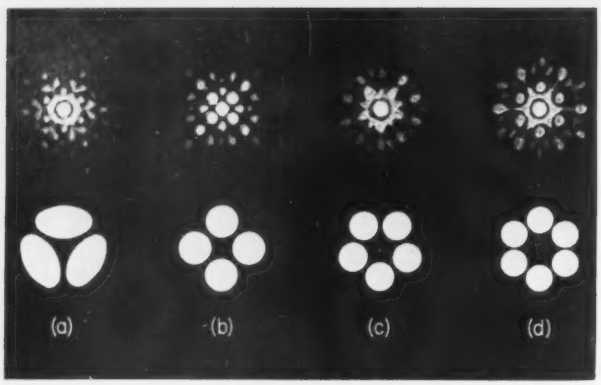

Fig. 6 (upper left). Three different arrangements of struts supporting an obstruction whose diameter is 0.2 that of the aperture. The diffraction effects produced by each setup are shown. There is a similarity between these patterns and those of the four-, one-, and three-strut arrangements.

Fig. 7 (above). Light energy spread by several forms of curved supports is represented in these drawings. Some observers object to the lack of spikes that may be used to locate the center of a bright star image.

Fig. 8 (left). Diffraction patterns of various assemblies of oval and circular openings. Because a large percentage of light is scattered from the central disk, these systems would not be suited for general telescope use.

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ports extending from one side only, and this pattern is comparable to that of the single vane. Fig. 6c, with two struts 120° apart, is similar to that of the three-strut arrangement.

Patterns resulting from several forms of curved supports are presented in Fig. 7. The spikes have disappeared, to be replaced by a faint-textured over-all pattern. Fig. 8 is for a series of masks having three, four, five, and six holes. In each case there is sufficient opaque space at the center to hide a $\frac{1}{5}$-aperture stop and its supports. Three oval openings (8a) make a pattern with a hexagonal first ring and some faint outer structure, but the setup gives surprisingly good results, considering the extent of the obstruction. Four circular openings produce a pattern of dots that is far from desirable, while five holes yield a pattern of 10-fold symmetry (8c).

Obviously, any support system having appreciable thickness will scatter some energy from the central disk and cause loss in contrast and resolution. However, in most systems W is less than 0.01, as in Fig. 4f. For most of the patterns reproduced here the width has been exaggerated to provide a strong result.

Of the two conventional supporting systems — three- and four-legged spiders — the first may be slightly better than the other (compare 4c and 5f). With very thin struts the spikes would be softer and less bothersome, and the more symmetrical spurious rings indicate better distribution of the scattered light in the ring system. With the three-legged unit, ad-

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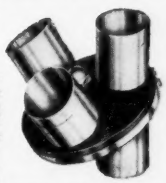

The Criterion Revolving Turret holds three eyepieces so that, as desired, the power of the telescope can be changed by merely turning the turret to a different ocular. Click stop insures positive and accurate positioning of each eyepiece. Turret holds eyepieces of standard 1¼" outside diameter. Fits into the holder of any refractor or reflector telescope that uses 1¼" eyepieces. Requires no alteration or adjustment and can be attached as easily as putting eyepiece into scope. Made of brass and aluminum with polished chrome-plated barrels.
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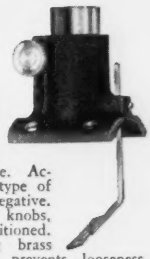

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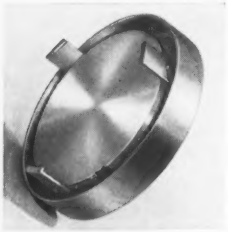

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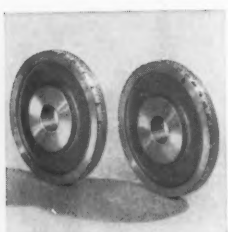

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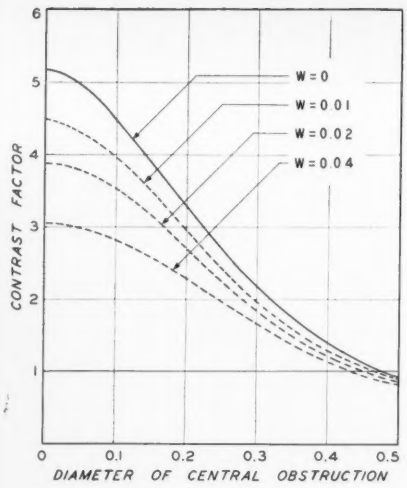

Fig. 9. The contrast factors for telescopes with various strut widths and central-obstruction sizes. In cases of relatively large central obstacles, the width of the struts is of little importance in determining contrast between star image and background.

justment of the diagonal is easier if the legs coincide with the three adjusting screws on the mirror cell. On the other hand, it is easier to center a four-legged spider.

No obvious advantage can be seen in the supports illustrated in Fig. 6, their special mechanical and aligning problems probably offsetting any slight improvement in the diffraction pattern. The supports in Figs. 4 and 5 are equal or slightly superior, all factors considered.

The results in Fig. 7 will come as a surprise to a great many amateurs who, since the late 1940's, have been advocating ring supports similar to 7a and 7b. The secondary support on my 8-inch Cassegrainian is a single ring, but since the instrument has never been used at over 80x, the loss of definition and the odd diffraction pattern have not become apparent.

At the 1948 Stellafane meeting, two 6-inch reflectors of about the same focal length were compared by Roland LaPelle. One had a spider like that in 7b, the other the standard four-legged type. The telescopes were placed within 10′ of each other to equalize the seeing, and a faint, difficult double star was examined through each instrument using the same eyepiece and Barlow lens combination. All observers agreed that the instrument with the circular spider performed better than the other. Unfortunately, no one checked alignment of the instruments, or compared them for optical excellence. Neither was a performance test made on a bright planet. Nevertheless, many amateurs left there that evening strong believers in the superiority of circular spiders.

The final part of Fig. 8 is reminiscent of the "antidiffraction" mask William A. Rhodes described in the April, 1957, issue of Sky and Telescope. His mask was sim-

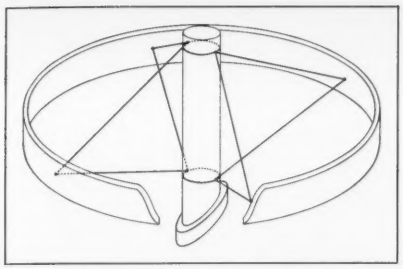

Fig. 10. A means of supporting the secondary mirror of a Newtonian telescope. The eight fine wires under tension do not run radially out from the center. Their thinness minimizes scattered light.

ilar to 8c, and it seemed, from low-power pictures of Rigel and its companion with and without the mask, that the five-opening arrangement performed better than the one with the secondary and struts uncovered. However, the results of Everhart and Kantorski indicate a lowering of the contrast and a scattering of light into the outer regions of the pattern that would affect critical observations of double stars or planets.

In their paper, Everhart and Kantorski calculate a contrast factor *C* for the annular aperture of Fig. 1 and also for the four-strut case of Fig. 4. It is the ratio of the light energy within the central disk to that in the rings and spikes. For the ideal case (no obstruction), *C* is 84/16, or 5.2. With the $\frac{1}{3}$-aperture central stop, *C* drops to 3.3 (shown by the solid line in Fig. 9), and adding four supports whose thickness is 0.01 the aperture causes a further reduction, to 2.95 (the upper dashed line in Fig. 9).

Clearly, it is desirable to keep the central obstruction as small as possible, and the supports thin. Curved spiders spread out the diffracted light and eliminate the spikes, but do not improve the contrast.

Another factor that should be considered was pointed out by André Couder in *l'Astronomie* for September-October, 1949. He found that even thin supports could, by thermal radiation, cause air currents that made the effective thickness of the struts larger than their actual size. He was able to reduce this effect by polishing and plating the supports, in contrast to the general practice of blackening everything inside the tube.

This air-current problem can be largely eliminated, and diffraction kept to a minimum, by using fine wires under tension for the supports. For stiffness the wires must *not* run radially outward from the center. This was discussed by E. H. Morse in the *Publications* of the Astronomical Society of the Pacific, *53*, 128, 1941. He pointed out that the wires must meet at a minimum of two different centers, being opposed in pairs somewhat like the spokes of a bicycle wheel. At Professor Everhart's suggestion, Paul Valleli of the Amateur Telescope Makers of Boston constructed such a system, similar to the one in Fig. 10, with good results.

A final conclusion from the Everhart-Kantorski work is that, whether wires or vanes are used, their width should not exceed one per cent of the aperture, if this is possible.

The experimental setup of Everhart and Kantorski is sketched in Fig. 11. The pinhole at **A** was 0.0018″, pierced in aluminum foil and illuminated by light from a tungsten filament concentrated on the pinhole by a condensing lens. It was situated at the focus of the 4-inch spherical mirror at **B**, which was stopped down to 2″ aperture. As its focal length was 120″, the focal ratio was f/60. The collimated light passed the central obstruction, supporting struts, or other obstacle at **C**, but it made no difference where this was placed in the collimated beam.

At **D** the image-forming mirror, also a 4-inch of 120″ focus, was stopped down to only $\frac{1}{2}$″, thus producing a diffraction pattern large enough to photograph. Finally, the slightly off-axis image was photographed or viewed with an eyepiece at **E**.

Since the mirror focal lengths were equal, the image of the pinhole at **E** was the same size as the pinhole itself. The diffraction pattern's central disk had a width of 0.0130″, so by comparison the pinhole was effectively a point source. The aberration introduced by tilting the mirrors (exaggerated in the sketch) was 0.0030″, negligible compared to the pattern size.

Although the camera's lens was not used, its shutter permitted varying the exposure times. Kodak Panatomic-X film recorded both the faint outer diffraction rings and the 600-times brighter central disk, but positive prints could not be made to show this wide range on a single print. The best reproduction was obtained by making pencil tracings of two prints of each pattern, one exposed for the inner region, the other for the faint outer parts. The drawings were done with soft pencil on white paper and reversed photographically to appear white on black.

R. E. C.

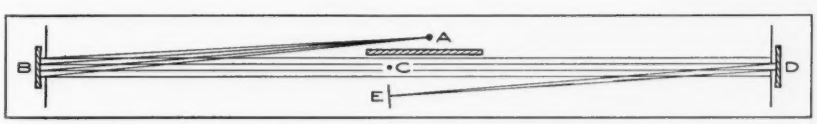

Fig. 11. Everhart and Kantorski used this optical arrangement to photograph diffraction patterns. Light from the artificial star A is collimated by mirror B, and passes the obstructing disk or wires at C. Then the telescope mirror D forms an image at E. where it may be drawn or photographed.

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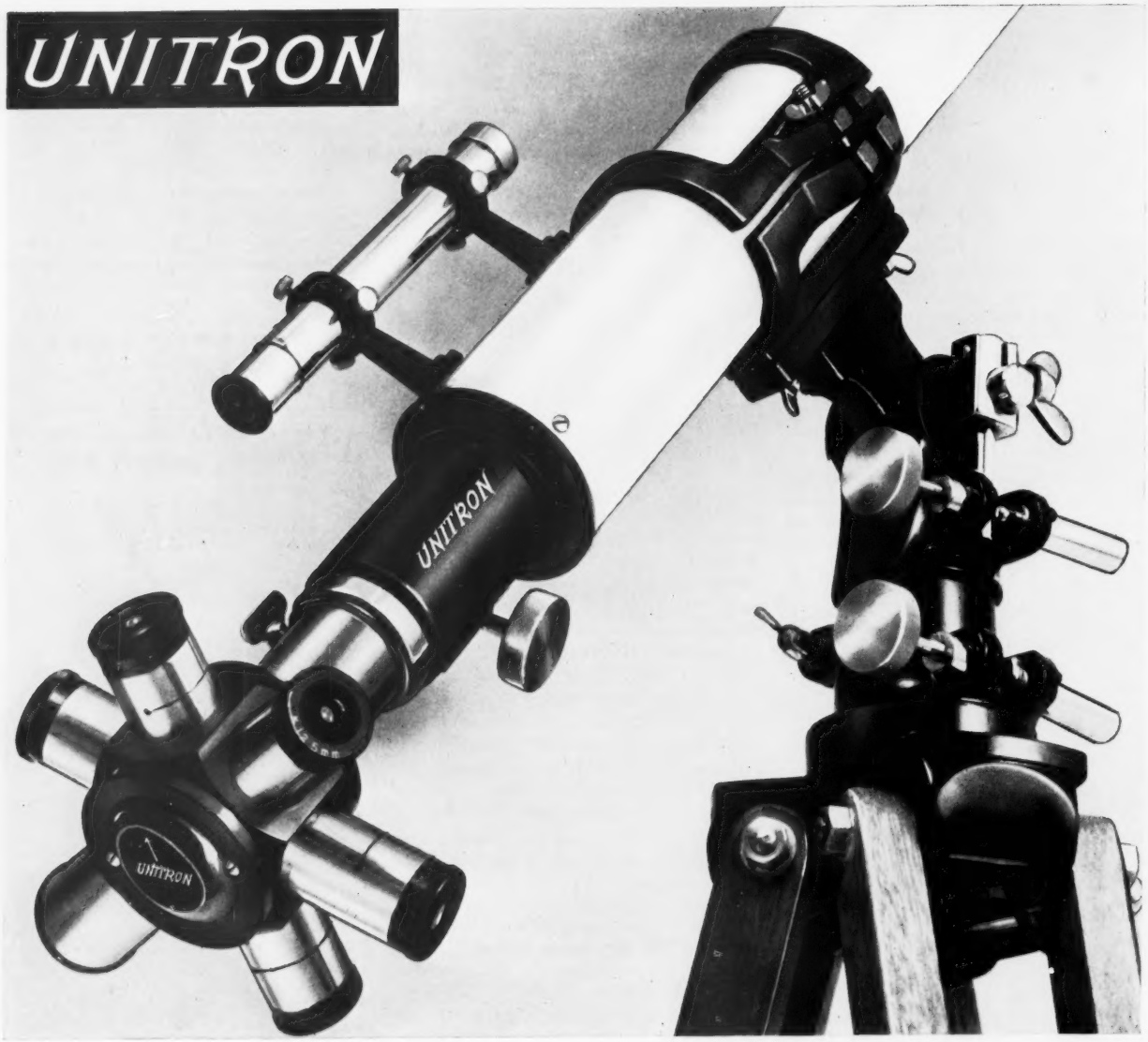

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CELESTIAL CALENDAR

Universal time (UT) is used unless otherwise noted.

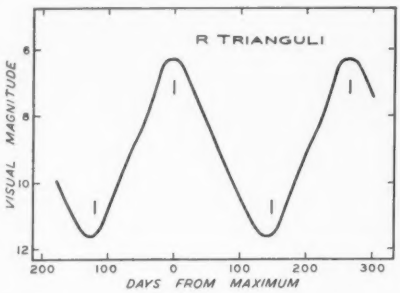
Three Red Variables in Triangulum

LOCATED about 4½° east of 4th-magnitude Gamma in Triangulum is the famous long-period variable star R Trianguli, bright enough in September and October to be seen in binoculars. Maximum light around magnitude 6.2 is due about September 24th, according to the American Association of Variable Star Observers, or only four days later, from elements given in the Moscow *General Catalogue of Variable Stars*. The period of R averages 266.4 days, and at minimum the magnitude is about 12. Variability was discovered in 1890 by the English amateur T. E. Espin and by Mrs. W. Fleming of Harvard Observatory. The 1950 position is $2^h\ 34^m.0$, $+34°\ 03'$.

Numbers on the accompanying chart indicate magnitudes of comparison stars, with the decimal points omitted; thus 58 is a star of magnitude 5.8. It is easy to estimate the brightness of R by comparison with two of these standard stars, one slightly brighter, the other slightly fainter than the variable. If such estimates are made at, say, weekly intervals for two months, they can be plotted on graph paper to provide a light curve from which the amateur can read off his own determination of the date of maximum.

On this same chart are two other interesting objects. W Trianguli is a red semiregular variable, whose light fluctuates between magnitudes 7 and 8½ in a cycle reported as 108 days. It has been relatively little studied.

The fine red color of 15 Trianguli, situated ½° northwest of R, is worth notice. This giant star of spectral class *M* was suspected of variability by several 19th-century visual observers, and the occurrence of small changes was demonstrated by photelectric measurements at Washburn Observatory about 30 years ago. Our chart gives its magnitude as 5.6.

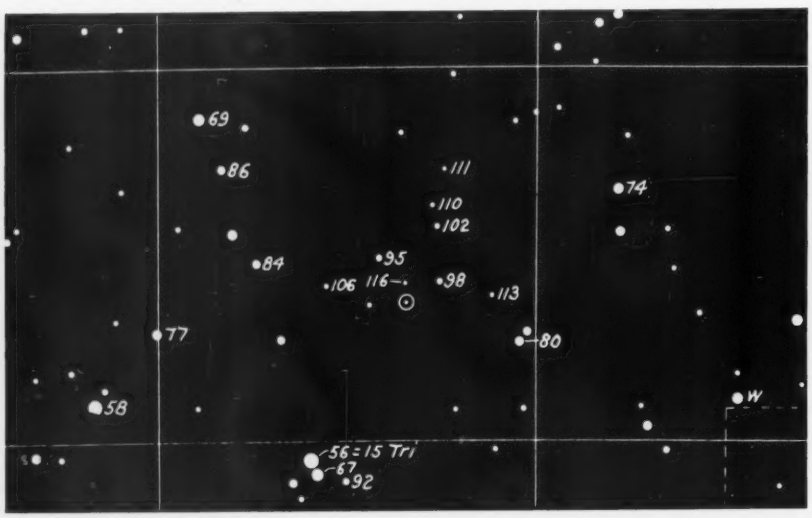


This mean light curve of R Trianguli, constructed from observations made by members of the American Association of Variable Star Observers, shows the average behavior of the variable between the years 1921 and 1949. This chart is adapted from Leon Campbell's "Studies of Long Period Variables."

MOON PHASES AND DISTANCE

Full moon	September	5, 11:19
Last quarter	September	12, 22:20
New moon	September	20, 23:13
First quarter	September	28, 1:13
Full moon	October	4, 22:17

	Distance	Diameter
September		
Perigee 2, 21h	226,300 mi.	32′ 48″
Apogee 14, 18h	251,400 mi.	29′ 32″
Perigee 29, 22h	229,400 mi.	32′ 22″
October		
Apogee 12, 13h	251,200 mi.	29′ 33″



The variable star R Trianguli is represented by the circled dot inside the one-degree square. W and 15 Trianguli are labeled. Visual magnitudes (with decimal points omitted) are given for the comparison stars, which range from 5.6 to 11.6. South is up in this reproduction of part of an AAVSO "b" chart.

SEPTEMBER 5TH LUNAR ECLIPSE

On the morning of September 5th, watchers in North America will be treated to a total eclipse of the moon. While only the very first part of the event can be seen in the East, the whole spectacle will be visible to observers on the West Coast.

The moon begins to enter the faint penumbra of the earth's shadow at 8:36 Universal time, but nearly an hour will elapse before it is appreciably darkened. First umbral contact is at 9:36, and the total phase begins 62 minutes later. Mid-eclipse is at 11:21, end of total phase begins at 12:05, and last umbral contact is at 13:07 UT. The moon leaves the penumbra 59 minutes later.

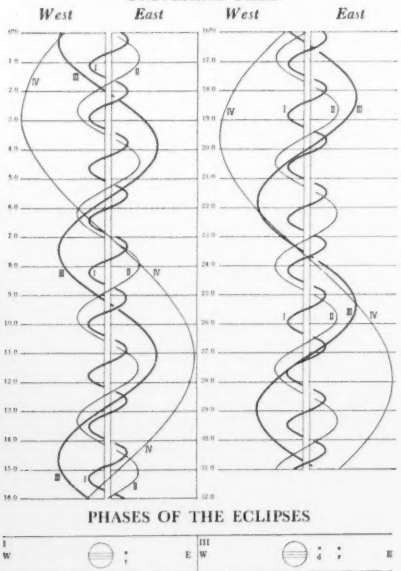
Details of this event, and a chart showing the passage of the moon through the shadow, appeared on page 91 last month.

JUPITER'S SATELLITES

The curves in the accompanying chart show the positions of Jupiter's four bright moons, as seen in an inverting telescope, with north at the bottom and east at the right. Each horizontal line is for 0h Universal time on the date specified, and the intersections of the line with the curves indicate the places of the satellites at that time. For other Universal times, interpolate between the 0h lines. The double vertical lines represent the planet's disk.

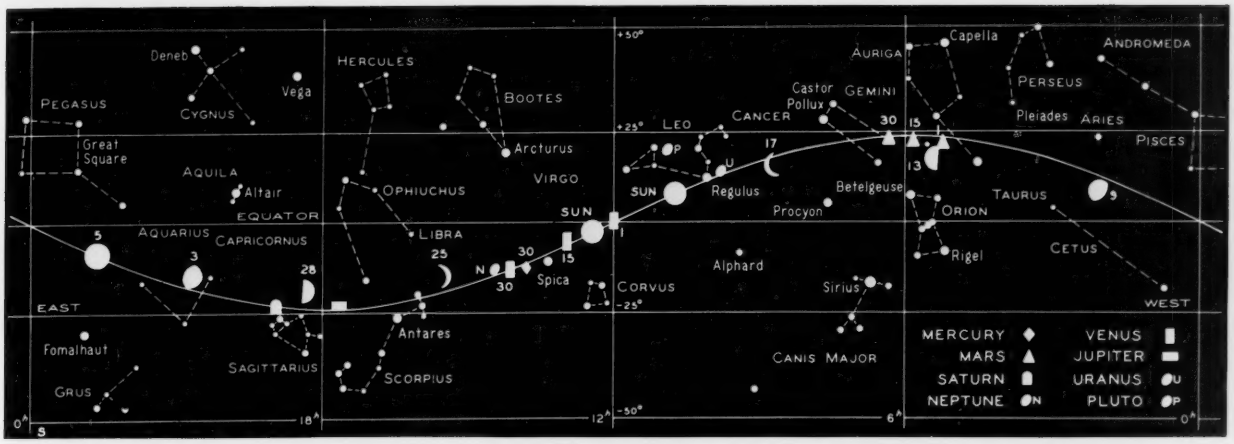
The lower section is intended to aid observations of the eclipses of Jupiter's moons; *d* is the point of disappearance of the satellite in Jupiter's shadow, *r* is the point of reappearance. The chart is from *The American Ephemeris and Nautical Almanac;* for further explanation, see page 446 of Sky and Telescope for May, 1960.

Jupiter's Satellites in September



ADDENDUM

In G. Fielder's article on lunar rills, page 334 of the April issue, the following addition should be made to the list of references: V. A. Firsoff, *Journal* of the British Astronomical Association, *66,* 314, 1956. This is an earlier and more explicit statement of Mr. Firsoff's ideas concerning the lunar grid system.



THE SUN, MOON, AND PLANETS THIS MONTH

The sun, on the ecliptic, is shown for the beginning and end of the month. The moon's symbols give its phase roughly, with the date marked alongside. Each planet is located for the middle of the month or for other dates shown. All positions are for 0h Universal time on the respective dates.

The sun will be partially eclipsed on September 20th for observers in nearly all parts of North America. At greatest eclipse, which occurs on Baffin Island, Canada, 61 per cent of the sun's diameter will be covered by the moon (see page 129).

Mercury is in the evening sky, but too near the sun to be seen this month.

Venus is fairly bright at magnitude −3.3, setting one hour after the sun. Look for it low in the western sky as soon as twilight begins. Venus will pass 3° north of Spica on the 20th. A very thin crescent moon will be near Venus on the evening of the 22nd, conjunction occurring at 22h Universal time, with the planet about 3° south of the moon.

Earth reaches heliocentric longitude 0° at 1:00 UT on September 23rd. This is the time of the equinox; autumn begins in the Northern Hemisphere and spring in the Southern.

The moon will be totally eclipsed on the morning of September 5th for observers in North America, western South America, the Pacific Ocean, Australia, and eastern Asia. In the United States, only the beginning of the eclipse will be visible in the eastern part of the country, but the entire event can be seen on the West Coast.

Mars will arrive at western quadrature (90° west of the sun) on the 24th. Then it will rise about 1½ hours before local midnight, being conspicuous (magnitude +0.4) in the eastern sky for the rest of the night. At midmonth, the reddish planet will be seen in telescopes as a small gibbous disk, 8″.2 in diameter and 86-per-cent illuminated.

Jupiter reaches eastern quadrature on September 17th, crossing the meridian at about sunset. Near the Ophiuchus-Sagittarius border, this golden yellow planet is of magnitude −1.8. Telescopically, Jupiter shows a noticeably elliptical disk, about 36″ in polar diameter and 39″ in equatorial diameter.

Saturn is in Sagittarius, east of Jupiter, and crosses the meridian about an hour after sunset in mid-September. It is visible in the southwestern sky as an object of magnitude +0.6 during the early evening, and sets around midnight. In telescopes, Saturn presents a disk 15″ in polar diameter, and the major axis of the rings is 39″. Saturn will be stationary in right ascension on the 15th, then resuming eastward motion among the stars.

Uranus is a 6th-magnitude object in Leo, rising two or three hours before the sun. On the 15th, it will be at right ascension 9h 43m.0, declination +14° 26′ (1950 co-ordinates).

Neptune is very low in the southwestern sky after sunset.

W. H. G.

UNIVERSAL TIME (UT)

TIMES used in Celestial Calendar are Greenwich civil or Universal time, unless otherwise noted. This is 24-hour time, from midnight to midnight; times greater than 12:00 are p.m. Subtract the following hours to convert to standard times in the United States: EST, 5; CST, 6; MST, 7; PST 8. To obtain daylight saving time subtract 4, 5, 6, or 7 hours, respectively. If necessary, add 24 hours to the UT before subtracting, in which case the result is your standard time on the day preceding the Greenwich date shown. For example, 6:15 UT on the 15th of the month corresponds to 1:15 a.m. EST on the 15th, and to 10:15 p.m. PST on the 14th.

VARIABLE STAR MAXIMA

September 3, W Lyrae, 181136, 7.9; 5, U Cygni, 201647, 7.2; 8, T Camelopardalis, 043065, 8.0; 10, S Ursae Majoris, 123961, 7.8; 11, T Centauri, 133633, 5.5; 12, R Camelopardalis, 142584, 7.9; 15, V Cassiopeiae, 230759, 7.9; 18, S Canis Minoris, 072708, 7.5; 22, T Columbae, 051533, 7.5; 23, U Herculis, 162119, 7.5; 24, R Trianguli, 023133, 6.2; 25, T Ursae Majoris, 123160, 7.7; 28, U Ceti, 022813, 7.5.

October 8, W Andromedae, 021143, 7.4.

These predictions of variable star maxima are by the AAVSO. Stars are listed only if brighter than magnitude 8.0 at an average maximum. Some, but not all of them, are nearly as bright as maximum two or three weeks before and after the dates for their maxima. The data given include, in order, the day of the month near which the maximum should occur, the star name, the star designation number, which gives the rough right ascension (first four figures) and declination (bold face if southern), and the predicted visual magnitude.

MINOR PLANET PREDICTIONS

Vesta, 4, will be a 7th-magnitude object in Sagittarius during September, and may be found with binoculars and the help of the chart on page 447 of the May issue.

MINIMA OF ALGOL

September 2, 12:33; 5, 9:21; 8, 6:10; 11, 2:58; 13, 23:47; 16, 20:36; 19, 17:24; 22, 14:13; 25, 11:01; 28, 7:50.

October 1, 4:39; 4, 1:27; 6, 22:16.

These minima predictions for Algol are based on the formula in the 1953 *International Supplement* of the Krakow Observatory. The times given are geocentric; they can be compared directly with observed times of the star's least brightness.

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Cat. No.	Size	Field at 1,000 yards	Type	Price, ppd.
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$1436	6 x 30 CF	395	"Zeiss"	18.75
$1435	6 x 30 IF	395	"Zeiss"	16.75
$1438	7 x 35 CF	341	"Zeiss"	20.75
$1437	7 x 35 IF	341	"Zeiss"	17.95
$1771	7 x 35 CF	341	American	23.50
$1439	7 x 35 CF	578	American*	35.00
$2191	7 x 50 CF	530	American**	42.50
$1106	7 x 50 CF	372	"Zeiss"	24.95
$-961	7 x 50 IF	372	"Zeiss"	22.50
$1503	7 x 50 CF	372	American	32.50
$1443	8 x 30 CF	393	"Zeiss"	21.00
$1229	8 x 30 IF	393	"Zeiss"	18.25
$1108	10 x 50 IF	275	"Zeiss"	26.75
$1442	20 x 50 CF	183	"Zeiss"	33.75
$1441	20 x 50 IF	183	"Zeiss"	31.75

*Wide-angle 11° **Wide-angle

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Brand new, coated optics, complete with pigskin case and neck straps.

Cat. No. $1576	6 x 30	$10.00 ppd.
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This telescope has a brilliant-image 48° apparent field; actually 325 feet at 1,000 yards. Can be adjusted for focusing 15 feet to infinity. 2" achromatic objective, focusing eyepiece 28-mm. f.l., Amici erecting system. Turret-mounted filters: clear, red, amber, and neutral. Lamp housing to illuminate reticle for night use. Truly the biggest bargain you were ever offered. Original Gov't. cost $200.

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Power	Field at 1,000 yards	Exit pupil diam.	Relative Brightness
15x	122 ft.	5.4 mm.	29
20	122	4.0	16
30	61	2.7	7
40	49	2.0	4
60	32	1.3	1

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$1207	12.5 mm. (½")	Symmetrical	6.00
$1251	16 mm. (⅝")	Erfle (wide-angle)	12.50
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COATED LENSES 75 cents extra.

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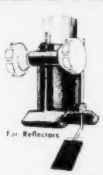

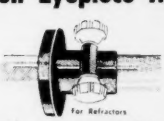

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REFLECTOR TYPE

Cat. No. $1976 (less diagonal holder) ..... $8.50 ppd.
Cat. No. $1982 DIAGONAL HOLDER ..... 1.00 ppd.

ASTRONOMICAL OBJECTIVES

• • • Air-spaced • • •

"THOSE WHO KNOW" BUY FROM US BECAUSE:

Each lens is thoroughly tested and guaranteed to resolve to Dawes' limit. They are corrected for the C and F lines (secondary chromatic aberration). The zonal spherical aberration and the chromatic variation of spherical aberration are negligible. The cells are machined to close tolerances so that they fit directly over or into our standard aluminum tubing, eliminating any mounting problems. Test a lens, or have any qualified person test it; we are certain that you will be satisfied. If not, take advantage of our money-back guarantee. *We offer the lowest-priced, hand-corrected, precision, American-made astronomical objective,* mounted in an aluminum cell. Our reputation for high-quality lenses has established us as the most reliable source in the industry.

HARD-COATED ON 4 SURFACES.

3¼" APERTURE f/15 — 48" F. L.	Cat. No. $1447	NOT COATED	$28.00 ppd.
	Cat. No. $1471	COATED	32.00 ppd.
4⅛" APERTURE f/15 — 62" F. L.	Cat. No. $1472	NOT COATED	$60.00 ppd.
	Cat. No. $1473	COATED	69.00 ppd.
6" APERTURE f/10 — 60" F. L.	Cat. No. $1861	UNMOUNTED	$150.00 ppd.
	Cat. No. $1860	MOUNTED	175.00 ppd.
6" APERTURE f/15 — 90" F. L.	Cat. No. $1863	UNMOUNTED	$150.00 ppd.
	Cat. No. $1862	MOUNTED	175.00 ppd.

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We have the largest selection of diameters and focal lengths in the United States available for immediate delivery. These are perfect magnesium-fluoride coated and cemented Gov't. surplus lenses made of finest crown and flint optical glass. Not mounted. Fully corrected. Tremendous resolving power.

● ALUMINUM TUBING and CELLS are in stock ●

Cat. No.	Diam.	F.L.	ppd.	Cat. No.	Diam.	F.L.	ppd.	Cat. No.	Diam.	F.L.	ppd.
$1476	(2⅛")	(10")	$12.50	$1520	(2⅛")	(50")	$12.50	$-957	(3¼")	(40")	$30.00
$1112	(2⅛")	(11¾")	12.50	$-851	(3-1/16")	(15")	21.00	$1155	(4")	(34½")	60.00
$1110	(2⅛")	(13")	12.50	$1158	(3⅛")	(19½")	28.00	$1460	(4¼")	(36")	60.00
$-958	(2⅛")	(15½")	9.75	$-822	(3-3/16")	(24½")	22.50	$1159*	(4⅜")	(42")	60.00
$1145	(2⅛")	(20")	12.50	$1092	(3¼")	(26")	28.00	$1225	(4⅜")	(42")	67.50
$-952	(2⅛")	(23½")	12.50	$1093	(3¼")	(28")	28.00	$1474*	(5-1/16")	(24¾")	75.00
$1431	(2⅛")	(30")	12.50	$1139	(3¼")	(30")	28.00	$1475	(5-1/16")	(24¾")	85.00
$1432	(2⅛")	(40")	12.50	$-955	(3¼")	(34½")	28.00	*Not coated.			

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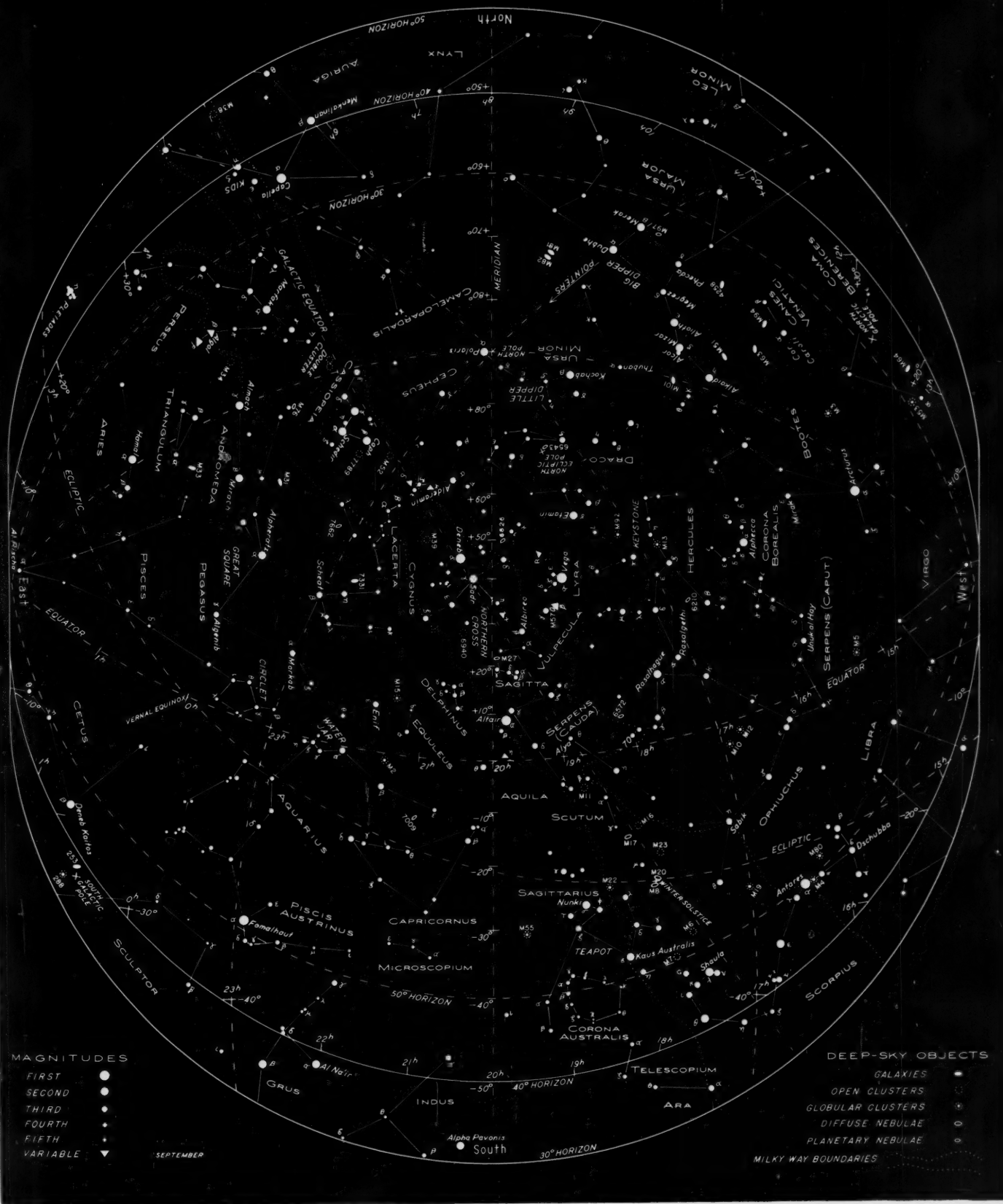
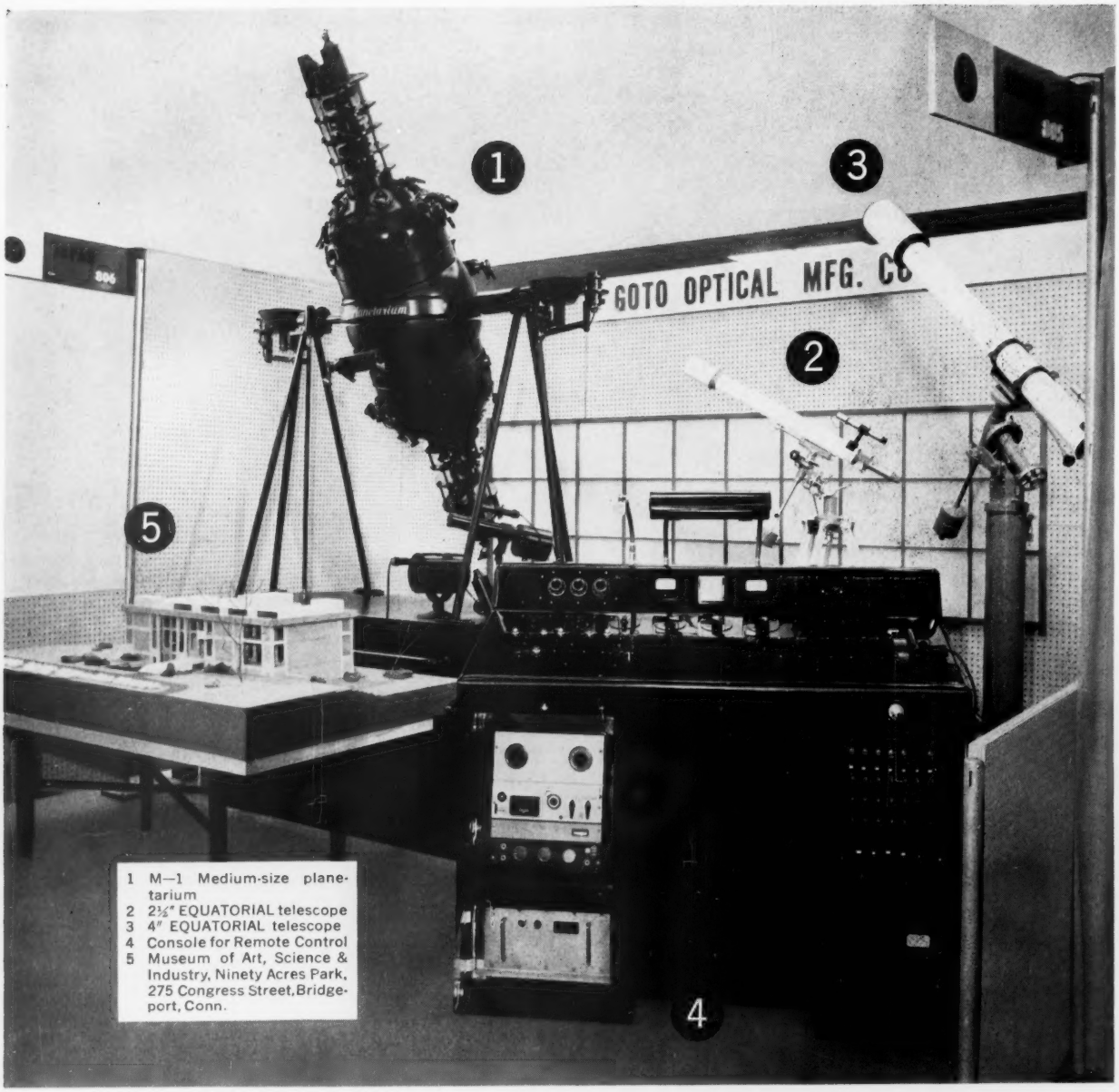


STARS FOR SEPTEMBER

The sky as seen from latitudes 30° to 50° north, at 9 p.m. and 8 p.m., local time, on the 6th and 21st of September, respectively; also, at 7 p.m. and 6 p.m. on October 6th and 22nd. For other dates, add or subtract ½ hour per week.

Binoculars bring rewarding sights in the cluster-rich Milky Way this month. Try the globular clusters M15 in Pegasus and M22 in Sagittarius, as well as the open clusters M11 in Scutum and M39 in Cygnus. All of these may be found with a little searching.



GOTO MEDIUM-SIZE PLANETARIUM

The Museum of Art, Science & Industry, Bridgeport, Connecticut is the first institution to install Goto's M-1 medium-size planetarium in its dome. It will open to the public in the fall of this year. The planetarium has won high acclaim when displayed at the 4th annual United States World Trade Fair in May 1960.

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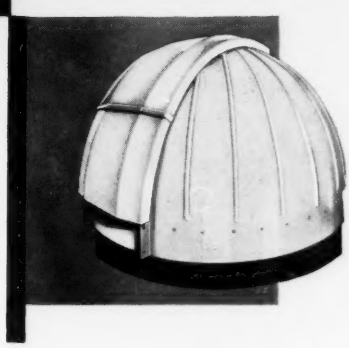
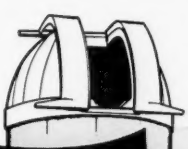
The ALL NEW ASTRO-DOMETTE

Astro-Domettes have been developed for high schools and junior colleges. These units are fabricated on an assembly line basis, resulting in high quality yet modest cost. Because sections are stamped or molded, dome components are uniform and interchangeable. Astro-Domettes are available in sizes of 8, 10 and 12 feet outside diameters. In the space age, progressive schools will want to include this new aid to education in their science department.



ASTRO-DOMETTES are available in pastel colors



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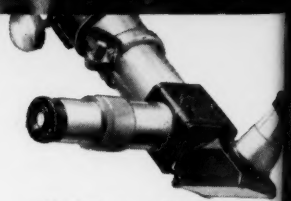

⁂† The Duetron, one of many exclusive Unitron accessories for multiplying viewing thrills, permits two people to view at the same time. It is shown mounted on a Unitron 4" Equatorial Telescope, Model 155.

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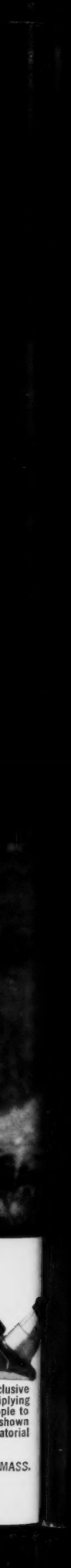
SEE PAGES 172 AND 173 FOR MORE ABOUT UNITRON.